SYSTEMATIC ANATOMY OF THE DICOTYLEDONS

A HANDBOOK FOR LABORATORIES OF PURE AND APPLIED BOTANY

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NYCTAGINEAE.

1. Review of the Anatomical Features. The anomalous structure of the stem (Fig. 155) and the occurrence of raphides or styloids are characteristic of the Order. The anomaly consists in the appearance, in the pericycle, of successive rings or strips of cambium, which produce secondary collateral vascular bundles and conjunctive tissue on their inner side. The conjunctive tissue is either prosenchymatous or parenchymatous; its structure, combined with the arrangement of the secondary vascular bundles, gives variety to the appearance of the transverse section of the stem. The prosenchymatous conjunctive tissue bears simple pits like the wood-prosenchyma of the vascular bundles, from which it is difficult to distinguish, and is sometimes traversed by typical medullary rays. The xylem-vessels have simple perforations. The outer portion of the pericycle generally contains isolated groups of sclerenchymatous fibres. The development of cork is superficial. In *Pisonia*, *Neea*, and *Leucaster* the stomatal apparatus follows the Rubiaceous type, whilst in *Mirabilis* and *Boerhaavia* each pair of guard-cells is surrounded by an indefinite number of ordinary epidermal cells. The hairy covering consists of clothing and glandular hairs. The former include the uniseriate trichomes of *Bougainvillaea*, which are composed of short cells, and the stellate hairs [1] of *Leucaster*, in which the stellate portion consists of a rather large number of unicellular rays. The glandular hairs (Fig. 154, *A*) generally consist of a row of cells, the enlarged terminal cell being in most cases ellipsoidal or clavate, more rarely spherical; the contents of this cell vary, but in the dry state they are usually brown (*Pisonia*, *Neea*, *Mirabilis*). A type intermediate between clothing and glandular hairs is presented by the branched trichomes (Fig. 154, *B*) composing the dense hairy covering on the lower side of the leaf of *Pisonia tomentosa*, Casar.; in these hairs the axis and branches are uniseriate; the terminal cells of the branches especially are commonly differentiated into long sacs filled with brown contents. Internal secretory organs are only found in *Okenia* and *Boerhaavia*, in which enlarged epidermal cells, filled with reddish-brown contents, give rise to a red striation of the leaves and floral organs. Oxalate of lime (Fig. 154, *C*) is excreted chiefly in the form of raphides and styloids, clustered crystals and a kind of crystal-sand (the latter in *Leucaster*) being also found. The deposition of crystalline granules, consisting of the same salt, in the cell-walls of the epidermis in the leaf and stem (Fig. 154, *A*), has been shown to take place in the genera *Mirabilis*, *Oxybaphus*, *Nyctaginia*, *Allionia*, *Boerhaavia*, *Acleisanthes*, *Okenia* and *Abronia*.

2. Structure of the Leaf. The researches published on the anatomy of the Nyctagineae almost always deal solely with the interesting anomalous structure of the axis, whilst the leaf-structure has practically not been investigated. And yet it would be important for systematic purposes to obtain some knowledge of the distribution of the two types of stomata which have been recorded in the Order, and also of the distribution of the trichomes (see above).

With the object of determining the different features which have been briefly mentioned above, I examined the structure of the leaf in *Mirabilis Jalapa*, L., *Bougainvillaea spectabilis*, Willd. (Tribe Mirabilieae), *Pisonia nitida*, Mart., *Neea compressa*, Schmidt (Tribe Pisonieae), and *Leucaster caniflorus*, Choisy (Tribe Leucastereae). The leaves in these plants have bifacial structure. The **stomata** are only found on the lower side of the leaf. In *Mirabilis* and *Bougainvillaea*, as stated above, they are surrounded by a variable number of ordinary epidermal cells exhibiting no special arrangement, whilst in the

[1] The stellate hairs of *Andradea* have not yet been carefully examined.

remaining cases they are accompanied on either side by one or more su sidiary cells placed parallel to the pore. The important points regarding th **trichomes** *investigate on the leaf, have also been mentioned in the general diagnosis.* Stellate hairs occur in *Leucaster* and *Andradea*; simple uniseriate hairs, composed of short cells, with a blunt terminal cell not greatly exceeding the others in length, are found in *Bougainvillaea spectabilis.* Glandular hairs occur in *Pisonia, Neea* and *Mirabilis*; they have a stalk of variable length, composed of a very variable number of cells, and a unicellular, spherical, or elongated ellipsoidal head (Fig. 154, *A*). The leaf of *Pisonia tomentosa*, Casar., as mentioned above, bears branched hairs, which have a glandular function (see above, and Fig. 154, *B*). The large epidermal cells of *Okenia* and *Boerhaavia* are filled with brownish-red, tanniniferous contents, and are differentiated as **secretory cells**; they were observed by Heimerl. The same author demonstrated the deposition of crystalline granules of **oxalate of lime** in the walls of the epidermal cells (Fig. 154, *A*) in the genera mentioned above. It should be noted that these genera belong to the Sub-tribes Boerhaavieae and Abronieae of the Tribe Mirabilieae, according to the classification of Bentham and Hooker; in the Sub-tribes Bougainvillaeeae and Boldoeae, and in the Tribes Pisonieae and Leucastereae[1] Heimerl sought for this feature in vain. The incrustation, as far as is known, is almost always present in all the species of a genus; it is only known to be absent in a few

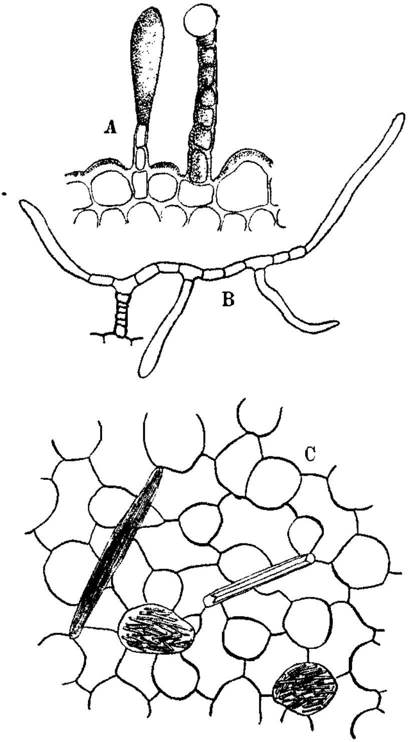


FIG. 154. A, Transverse section through the epidermis of *Boerhaavia repens*, L.; B, Branched trichome of *Pisonia tomentosa*, Casar; C, Crystalline elements in the spongy tissue of *P. nitida*, Mart.—Original.

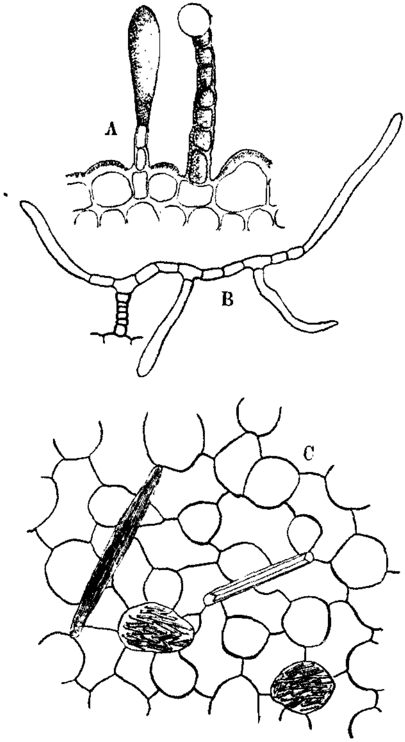
[1] Species of *Bougainvillaea, Tricycla, Boldoa, Collignonia, Reichenbachia, Pisonia, Neea, Phaeoptilum, Cephalotomandra, Leucaster* and *Cryptocarpus* were examined.

species of ***Mirabilis*** (*M. Jalapa*, L., *M. longiflora*, L., *M. Oaxacae*, Heim. and *M.* '***Wrightiana***, Decne.'). In most cases the deposition is met with in the epidermis, both of the leaf and stem. The variations found in the individual species depend on (*a*) the occurrence of the deposition in both the upper and lower epidermis of the leaf, or only in the lower, (*b*) the presence of the deposition in the outer, inner, and lateral walls of the epidermal cells, and (*c*) the different degrees of abundance of the excretion. The layer of granules in the outer wall is directly covered by the cuticle, and is bounded towards the cell-lumen by a lamella devoid of granules. Deposition is rare in the lateral walls, but common in the internal walls of the epidermal cells; in these cases also the lamella of the wall adjoining the lumen is devoid of granules. The incrustation may also extend to the walls of the hairs, whilst the stomata are invariably free from it. In some cases the deposition is so abundant, that the leaves and stems of certain species appear grey or whitish, the stem of *Boerhaavia elegans*, Choisy being chalky white[1]. In *Oxybaphus* a study of the development has shown that the incrustation only appears at a relatively late stage, and originates in the cell-wall itself. Regarding the mode of excretion of oxalate of lime, the following statements may be added. Bundles of raphides have been shown to occur in species of *Bougainvillaea*, *Cryptocarpus*, *Mirabilis* and *Oxybaphus*, raphides and styloids in species of *Neea*, *Phaeoptilum* and *Pisonia*, styloids alone in *Eggersia*. In the leaf of *Pisonia nitida* each cell of the palisade-tissue contains a rather small clustered crystal, whilst styloids and bundles of typical raphides or of short acicular crystals more like styloids also occur in the mesophyll (Fig. 154, *C*). In the sacs containing crystal-sand in the leaf of *Leucaster caniflorus* there are either tetrahedral crystalline granules or rather small acicular or prismatic crystals.

3. STRUCTURE OF THE AXIS. **Anomalous structure of the stem** apparently occurs in all the woody species, and is also found in a certain number of the herbaceous species. It has been recorded by various authors (Regnault, Unger, Grönlund, Petersen, De Barry, Radlkofer, Solereder, H. Schenck, Houlbert) in numerous species of the genera *Mirabilis*, *Oxybaphus*, *Boerhaavia*, *Bougainvillaea*, *Pisonia*, *Eggersia*, *Phaeoptilum*, *Neea*, *Leucaster* and *Cryptocarpus*. The constant feature of the anomaly consists in the presence of more than one ring of vascular bundles in the transverse section of the axis (Fig. 155). The course of development of the anomaly has been referred to above. The secondary vascular bundles exhibit a concentric or irregular arrangement; they are embedded in conjunctive tissue, and together with the latter form the ' wood ' of the Nyctagineae; in most members of the Order the conjunctive tissue, except the innermost portion (on this point see below), consists chiefly of prosenchymatous cells, which are provided with simple pits and usually have rather thick walls, though in rare cases the thickening is but slight (*Pisonia fragrans*, Desf.). Adjoining the phloem-groups of the vascular bundles there are frequently a few unlignified and thin-walled or lignified parenchymatous cells, and in certain members of the Order (in all the species of *Pisonia* and *Neea* investigated by Houlbert and myself, except *P. hirtella*, H. B. K.) narrow, radial strips of tissue traverse the conjunctive tissue, and in their composition correspond to the medullary rays in woods with normal structure. The thin-walled conjunctive tissue is developed in greater abundance in a minority of the species investigated. Thus in *Bougainvillaea spectabilis* the secondary bundles, in which the xylem consists of vessels and prosenchyma, are separated by rather broad parenchymatous strips of tissue, resembling medullary rays,

[1] The dull surface of the stems and leaves in some species of *Pisonia* and *Neea*, due to a deposition of wax, must not be confounded with this feature (Heimerl).

remaining cases they are accompanied on either side by one or more subsidiary cells placed parallel to the pore. The important points regarding the **trichomes** investigated on the leaf, have also been mentioned in the general diagnosis. Stellate hairs occur in *Leucaster* and *Andradea*; simple uniseriate hairs, composed of short cells, with a blunt terminal cell not greatly exceeding the others in length, are found in *Bougainvillaea spectabilis*. Glandular hairs occur in *Pisonia*, *Neea* and *Mirabilis*; they have a stalk of variable length, composed of a very variable number of cells, and a unicellular, spherical, or elongated ellipsoidal head (Fig. 154, *A*). The leaf of *Pisonia tomentosa*, Casar., as mentioned above, bears branched hairs, which have a glandular function (see above, and Fig. 154, *B*). The large epidermal cells of *Okenia* and *Boerhaavia* are filled with brownish-red, tanniniferous contents, and are differentiated as **secretory cells**; they were observed by Heimerl. The same author demonstrated the deposition of crystalline granules of **oxalate of lime** in the walls of the epidermal cells (Fig. 154, *A*) in the genera mentioned above. It should be noted that these genera belong to the Sub-tribes Boerhaavieae and Abronieae of the Tribe Mirabilieae, according to the classification of Bentham and Hooker; in the Sub-tribes Bougainvillaeeae and Boldoeae, and in the Tribes Pisonieae and Leucastereae[1] Heimerl sought for this feature in vain. The incrustation, as far as is known, is almost always present in all the species of a genus; it is only known to be absent in a few



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species of *Mirabilis* (*M. Jalapa*, L., *M. longiflora*, L., *M. Oaxacae*, Heim. and *M.* '*Wrightiana*, Decne.'). In most cases the deposition is met with in the epidermis, both of the leaf and stem. The variations found in the individual species depend on (*a*) the occurrence of the deposition in both the upper and lower epidermis of the leaf, or only in the lower, (*b*) the presence of the deposition in the outer, inner, and lateral walls of the epidermal cells, and (*c*) the different degrees of abundance of the excretion. The layer of granules in the outer wall is directly covered by the cuticle, and is bounded towards the cell-lumen by a lamella devoid of granules. Deposition is rare in the lateral walls, but common in the internal walls of the epidermal cells; in these cases also the lamella of the wall adjoining the lumen is devoid of granules. The incrustation may also extend to the walls of the hairs, whilst the stomata are invariably free from it. In some cases the deposition is so abundant, that the leaves and stems of certain species appear grey or whitish, the stem of *Boerhaavia elegans*, Choisy being chalky white[1]. In *Oxybaphus* a study of the development has shown that the incrustation only appears at a relatively late stage, and originates in the cell-wall itself. Regarding the mode of excretion of oxalate of lime, the following statements may be added. Bundles of raphides have been shown to occur in species of *Bougainvillaea*, *Cryptocarpus*, *Mirabilis* and *Oxybaphus*, raphides and styloids in species of *Neea*, *Phaeoptilum* and *Pisonia*, styloids alone in *Eggersia*. In the leaf of *Pisonia nitida* each cell of the palisade-tissue contains a rather small clustered crystal, whilst styloids and bundles of typical raphides or of short acicular crystals more like styloids also occur in the mesophyll (*Fig.* 154, *C*). *In the sacs containing crystal-sand in the leaf of Leucaster caniflorus* there are either tetrahedral crystalline granules or rather small acicular or prismatic crystals.

3. Structure of the Axis. **Anomalous structure of the stem** apparently occurs in all the woody species, and is also found in a certain number of the herbaceous species. It has been recorded by various authors (Regnault, Unger, Grönlund, Petersen, De Barry, Radlkofer, Solereder, H. Schenck, Houlbert) in numerous species of the genera *Mirabilis*, *Oxybaphus*, *Boerhaavia*, *Bougainvillaea*, *Pisonia*, *Eggersia*, *Phaeoptilum*, *Neea*, *Leucaster* and *Cryptocarpus*. The constant feature of the anomaly consists in the presence of more than one ring of vascular bundles in the transverse section of the axis (Fig. 155). The course of development of the anomaly has been referred to above. The secondary vascular bundles exhibit a concentric or irregular arrangement; they are embedded in conjunctive tissue, and together with the latter form the 'wood' of the Nyctagineae; in most members of the Order the conjunctive tissue, except the innermost portion (on this point see below), consists chiefly of prosenchymatous cells, which are provided with simple pits and usually have rather thick walls, though in rare cases the thickening is but slight (*Pisonia fragrans*, Desf.). Adjoining the phloem-groups of the vascular bundles there are frequently a few unlignified and thin-walled or lignified parenchymatous cells, and in certain members of the Order (in all the species of *Pisonia* and *Neea* investigated by Houlbert and myself, except *P. hirtella*, H. B. K.) narrow, radial strips of tissue traverse the conjunctive tissue, and in their composition correspond to the medullary rays in woods with normal structure. The thin-walled conjunctive tissue is developed in greater abundance in a minority of the species investigated. Thus in *Bougainvillaea spectabilis* the secondary bundles, in which the xylem consists of vessels and prosenchyma, are separated by rather broad parenchymatous strips of tissue, resembling medullary rays,

[1] The dull surface of the stems and leaves in some species of *Pisonia* and *Neea*, due to a deposition of wax, must not be confounded with this feature (Heimerl).

when seen in a transverse section of the stem; parenchymatous conjunctive tissue is also insinuated between the secondary bundles in a tangential direction. *B. fastuosa*, Hrcq. presents similar features, according to Houlbert. In *Boerhaavia plumbaginea*, Cav. (Petersen) and *B. arborea*, Lag. the thin-walled, parenchymatous, conjunctive tissue is also rather abundant. In these species the phloem-groups and the adjoining conjunctive elements combine to form concentric annular or band-shaped strips of tissue. The innermost portion of the conjunctive tissue, formed by the secondary meristem at the commencement of its cambial activity, is differentiated so as to resemble a pith in many members of the Order. Owing to this fact the leaf-trace bundles, and sometimes also the innermost secondary vascular bundles, often

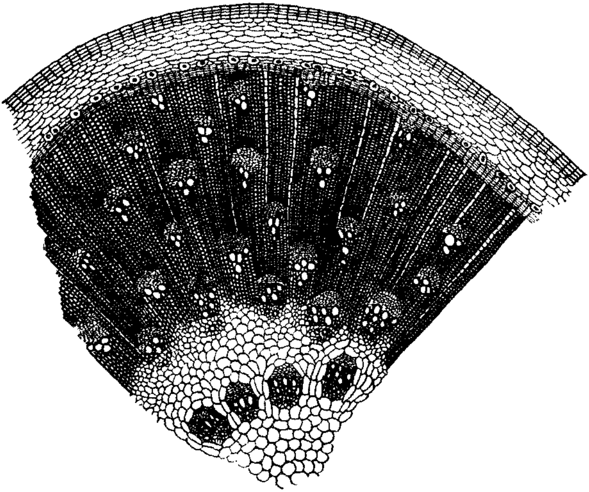

FIG. 155. Transverse section through the stem of *Pisonia nigricans*, Sw.—Original.

appear to be medullary (*Mirabilis* and *Oxybaphus*, according to De Bary). Probably the medullary vascular bundles, which I met with in all the species of *Bougainvillaea*, *Cryptocarpus*, *Pisonia* and *Neea* named in my 'Holzstruktur,' are likewise only apparently medullary; they are wanting in *Leucaster caniflorus* and (according to Petersen) in *Boerhaavia plumbaginea*.

Regarding the component parts of the vascular bundles the following facts remain to be mentioned. The **xylem** contains: (*a*) pitted vessels with simple perforations accompanied by reticulately perforated septa in the species of *Boerhaavia* (Dickson, Petersen); (*b*) prosenchyma; (*c*) parenchyma; (*d*) in the leaf-trace bundles, spiral tracheae which can be unrolled The latter elements, however, sometimes also occur in vascular bundles which from their position, must be regarded as inner secondary bundles, as has been shown by De Bary in the case of *Mirabilis*, by Petersen in *Boerhaavia* and *Bougainvillaea*, and by myself in species of *Neea* and *Pisonia*. In the ordinary

cases, in which the conjunctive tissue is formed by prosenchyma, the xylem-portions of the vascular bundles have not a distinct boundary. Together with the conjunctive tissue they form a connected xylem-mass, in which the phloem-groups of the vascular bundles are embedded like the islands of soft bast in *Strychnos*.

External to the parenchymatous pericycle, in which the anomalous growth in thickness of the stem takes place, a zone of small, isolated groups of sclerenchymatous fibres is present in the species of *Bougainvillaea, Cryptocarpus, Leucaster, Pisonia* and *Neea* examined by me; these elements are wanting in *Mirabilis Jalapa* and *Oxybaphus viscosus* (Regnault). The **cork** arises subepidermally in *Bougainvillaea spectabilis* (according to H. Schenck), and in *Pisonia* and *Boerhaavia* (according to Petersen), whilst it is formed in a deeper cell-layer of the primary cortex in *Neea parviflora* (according to Petersen).

The **anomalous structure**, as far as is known, extends also to the **roots** (*Mirabilis* with parenchymatous conjunctive tissue and concentric arrangement of the secondary vascular bundles, according to De Bary; *Bougainvillaea spectabilis* and *Pisonia nitida*, according to Avetta).

Literature: Unger, Bau u. Wachst. d. Dicotyledonenst., Petersburg, 1840.—Nägeli, Beitr. z. wiss. Bot., i. Heft, 1858, pp. 119–21.—Regnault, Anat. d. quelques tiges d. Cyclosp., Ann. sc. nat., ser. 4, t. xiv, 1860, pp. 144–9 and pl. ix.—Grönlund, Stamm. og. gren. anat. bygn. hos *Neea*, etc., Vidensk. Meddel. nat. For. Kjöbenhavn 1872, 19 pp. (French résumé) and Tab.—Finger, Anat. etc. von *Mirabilis Jalapa*, Diss., Bonn, 1873, 25 pp.—Moller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 35–6 and 331.—De Bary, Vergl. Anat. 1877, especially p. 607 et seq.—Dickson, in Transact. and Proceed. bot. Soc. of Edinburgh, vol. xiv, 1880, p. 121 et seq.—Petersen, Nyctag.-Stæng. Histolog. etc., Bot. Tidsskrift, Bd. 11, 1879–80, pp. 149–76, Tab. iv–v and French resumé pp. (16)–(19).—Radlkofer, in Abh. naturw. Ver. Bremen 1883, p. 435 et seq.—Morot, Péricycle, Ann. sc. nat., sér. 6, t. xx, 1885, especially p. 282 et seq.—Hérail, Tige des Dicotyled., Ann. sc. nat., sér. 7, t. ii, 1885, pp. 246–7.—Solereder, Holzstr., 1885, pp. 207–10.—Heimerl, Einlag. v. Calcium-oxalat etc., Sitz.-Ber. Wiener Akad., Bd. xciii, Abt. 1, 1886, sep. copy, 16 pp. and 1 Tab.—[Avetta, Anomalie di struttura nelle radici delle dicotyled., Ann. dell' Ist. bot. di Roma 1887, p. 10.]—Heimerl, Anat. d. N., Denkschr. Wiener Akad., Bd. 53, Abt. 2, 1887, pp. 61–78 and 3 Tab.; only treats of structure of flowers and fruit!—Petersen, Stængelbygn. hos *Eggersia*, Bot. Tidsskr., Bd. 16, 1888, pp. 216–20, Tab. iv and French résumé p. (9) and Bot. Centralbl. 1888, iii, pp. 27–28.—Eiselen, Rhaphiden, Diss., Halle a. S., 1888, p. 13.—Kohl, Kalks. etc., 1889, p. 79.—Heimerl, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 b, 1889, p. 15.—Houlbert, Struct. comp. du bois sec. dans les Apétales, Paris, Thèse, 1893, pp. 75–82, sep. copy from Ann. sc. nat., sér. 7, t. xvii.—H. Schenck, Anat. d. Lianen, 1893, pp. 56–8 and 252, Tab. ii.

ILLECEBRACEAE.

In this Order, which is mainly composed of herbaceous plants, the anatomy has been little investigated. From the few facts known it appears that in the structure of the axis the following features promise to afford a diagnosis of the Order: the usually normal structure of the stem; the lack of true medullary rays in the wood; the simple perforations of the vessels; the bordered pitting of the wood-prosenchyma; and the superficial development of cork. The stomata are generally surrounded by three or more epidermal cells; in *Scleranthus* the Caryophylleous type is found. The hairy covering consists of unicellular or uniseriate clothing hairs, which are mostly simple, rarely (*Pollichia*) branched, whilst uniseriate glandular hairs with a unicellular head are very rare (*Dysphania*). Internal secretory receptacles are not present. Oxalate of lime occurs in the form of large clustered crystals, and in *Gymnocarpos* also as crystal-sand. Anomalous structure of the stem in the form of successive rings of growth has been shown to occur in *Pollichia campestris*, Sol. and species of *Corrigiola*.

The **structure of the leaf** has been examined by Volkens in a number of desert-plants (*Pteranthus* '*dichotomus*, Forsk.,' *Herniaria hemistemon*, J. Gay, *Paronychia desertorum*, Boiss., *Gymnocarpos decandrum*, Forsk.), and

by me in *Pollichia campestris*, Sol., *Anychia dichotoma*, Michx., *Paronychia capitata*, Lam., *Pteranthus echinatus*, Desf. and *Scleranthus perennis*, L. The leaf-structure is commonly centric (e.g. *Pteranthus dichotomus* and *Gymnocarpos decandrum*). The **stomata** are usually found on both sides of the leaf, and either lie in the same plane as the surface of the leaf, or (*Pteranthus dichotomus* and *Gymnocarpos decandrum*) are strongly depressed. In the species which I examined, with the exception of *Scleranthus perennis*, the stomata are surrounded by three or more epidermal cells, showing no special mode of arrangement; in *Scleranthus* the stomata are parallel to one another, the pore being parallel to the median vein, and they possess two subsidiary cells, placed transversely to the pore. The following features are adaptations to a desert-climate: a deposition of wax on the leaf-surface in *Gymnocarpos decandrum*; high epidermal cells in the leaf of *Pteranthus dichotomus* and *Herniaria hemistemon*; bladder-like differentiation of the epidermal cells in the neighbourhood of the margin and above the midrib of the leaf in *Pteranthus dichotomus*; and central aqueous tissue in the leaf of *Gymnocarpos decandrum*.

The clothing **hairs** are mostly simple and unicellular (*Herniaria, Paronychia, Anychia*), or uniseriate (*Scleranthus*). The branched trichomes of *Pollichia campestris* are generally two-armed, the main axis and the arms consisting of a single row of cells. In the floral region of *Pteranthus echinatus* there are uniseriate trichomes of varying length, composed of few or many cells, and provided with a capitate swollen terminal cell; they practically have no glandular function. On the other hand the similarly constructed capitate hairs in the species of *Dysphania* (e.g. *D. myriocephala*, Benth.) are glandular; the species of this genus were described by Bentham, Flor. Austral., as slightly glandular. **Oxalate of lime** is often found in the mesophyll in the form of large clustered crystals (in *Pteranthus dichotomus* and *Gymnocarpos decandrum*, and also in the five species investigated by me): the primary cortex of *Gymnocarpos decandrum* contains large cells, which in place of clustered crystals enclose a compact mass of crystal-sand consisting of oxalate of lime.

The **structure of the axis**, like that of the leaf, has been little investigated; it was examined by me in *Pollichia campestris*, Sol. and *Gymnocarpos decandrum*, Forsk., by Regnault in *Paronychia bonariensis*, *Anychia dichotoma* and *Corrigiola littoralis*, and by Petersen with reference to the pericycle in species of *Illecebrum*, *Pollichia*, *Paronychia*, *Herniaria*, *Corrigiola*, *Gymnocarpos*, *Pteranthus*, *Cometes* and *Scleranthus*. In the structure of the wood the most noteworthy feature is the absence of true medullary rays in species in which the xylem-portions of the vascular bundles unite to form a ring (*Pollichia campestris*, *Gymnocarpos decandrum*, *Paronychia bonariensis*, *Anychia dichotoma*). In *Pollichia* and *Gymnocarpos* the diameter of the vessels is not great (·02–·03 mm.); they have rather thick walls and simple perforations (denticulate at the margin in *Pollichia campestris*). Spiral thickening of the vessel-wall is found in *Gymnocarpos decandrum*. Typical bordered pitting has been demonstrated in the wood-prosenchyma, not only in *Pollichia* and *Gymnocarpos*, but also in the species examined by Regnault. A sclerenchymatous pericycle is of frequent occurrence in the cortex (in the species examined by Petersen and Regnault); in species with a considerable amount of growth in thickness it becomes split up into small sclerenchymatous groups. The development of cork takes place subepidermally in *Paronychia bonariensis*.

Anomalous structure of the axis, in the form of concentric rings of vascular bundles, is found in *Pollichia campestris*, and according to Petersen in *Corrigiola littoralis* and *C. telephiifolia* (also in the root of *C. littoralis*, according to Lohrer). The second ring of vascular bundles in *Pollichia* (and probably also in *Corrigiola*) is produced by a secondary meristem, which arises in the inner parenchymatous portion of the pericycle.

Literature: Regnault, Anat. d. qq. tiges d. Cyclosp., Ann. sc. nat., sér. 4, t. xiv, 1860, pp. 112-17 and pl. 7.—Solereder, Holzstr., 1885, pp. 210, 211.—Lohrer, Wurzeln, in Wigand, Bot. Hefte, ii, 1887, pp. 26-7 and Tab. ii.—Volkens, Aegypt.-arab. Wüste, 1887, pp. 103-5 and Tab. vii, x and xv. Petersen, Mom. til Caryophyll. anat., Bot. Tidsskrift, Bd. 16, pp. 187-202, Tavle 5 and French resumé p. (8).

AMARANTACEAE.

1. Review of the Anatomical Features. With few exceptions (*Achatocarpus, Cladothrix*) the woody members of this Order are distinguished by the same anomalous structure of the axis as occurs in the related Nyctagineae and Chenopodiaceae (Fig. 157). The vascular bundles scattered in the conjunctive tissue exhibit concentric or irregular arrangement in a transverse section of the stem, and the conjunctive tissue either consists of prosenchyma with simple pits or of unlignified parenchyma; when prosenchymatous, medullary rays are sometimes developed in it. The perforations of the vessels are simple in all cases. The formation of periderm takes place superficially in *Amarantus*. The stomata do not possess any special subsidiary cells. Internal secretory organs are wanting. The hairy covering is for the most part formed by ordinary unicellular or uniseriate trichomes, and by capitate hairs with a uniseriate stalk and a unicellular head. The following are special forms of hair (Fig. 156)[1]: the trichomes of *Ptilotus*, with two arms or rarely more, both the stalk and the arms being composed of a row of cells; the two-armed trichomes of *Dicraurus*, in which the terminal cell has equal arms; the stellate hairs of species of *Iresine* with a many-rayed terminal cell, occasionally passing by transitional forms into two-armed hairs with arms of unequal length; finally the candelabra-hairs of *Alternanthera, Cladothrix*, and *Telanthera*, in which each tier is composed of a many-rayed cell. The walls of the various forms of hair (with the exception of the capitate hairs) are in many cases raised into numerous small papillae.

2. Structure of the Leaf. The leaf-structure has been little investigated. The species which I examined, representing the three tribes (*Amarantus Blitum*, L. and *A. polygonoides*, L., *Celosia trigyna*, L., *Gomphrena desertorum*, Mart.), have **stomata** on both sides of the leaf. The stomata are surrounded by three or more ordinary epidermal cells. The size of the **epidermal cells** and the nature of their lateral margins vary in the species mentioned above. *Celosia trigyna* is distinguished by papillose or bladder-like protrusion of the epidermal cells on the lower side of the leaf opposite the vascular bundles of the veins. In *Amarantus Blitum, A. polygonoides* and other species, *Gomphrena desertorum* and other species, *Alternanthera muscoides*, Benth. et Hook., and *Philoxerus vermicularis*, R. Br., the vascular bundles of the smaller and larger **veins**, including their ultimate ramifications, are surrounded by a characteristic sheath of large and almost cubical parenchymatous cells (Fig. 156, *A–B*); this is a feature which only rarely occurs amongst Dicotyledons, although common amongst Monocotyledons. According to Johow and Warming, *Philoxerus vermicularis* possesses a decidedly peculiar type of leaf-structure, viz. rather massive aqueous tissue on the lower side of the leaf; stomata in the upper epidermis only; assimilatory tissue only on the upper side; and lastly, vascular bundles (of the veins) with a parenchymatous sheath of cells with wide lumina, and radial arrangement of the adjoining cells of the palisade-tissue.

Oxalate of lime is present in the leaf in the form of clustered crystals or crystal-sand. Solitary crystals are rare (axis of *Alternanthera procumbens*, according to Nemnich). Crystal-sand and clustered crystals sometimes occur

[1] The stellate hairs, mentioned by systematists as investing certain species of *Trichinium*, and the hairy covering of *Calicorema*, described by them as furfuraceous, have still to be investigated.

side by side in the leaf, as in *Amarantus Blitum* and *A. polygonoides*, where large clustered crystals are found in the mesophyll, whilst sand occurs in the veins; in other cases clustered crystals only are found in the leaf (*Gomphrena desertorum*), or sand only (*Celosia trigyna*); in *Celosia trigyna* the sand in the cells of the mesophyll consists of coarse granules or fragments, whilst that in the veins is more finely granular. Crystal-sand is the characteristic form of excretion in the Order. Besides occurring in the leaf of *Amarantus* and

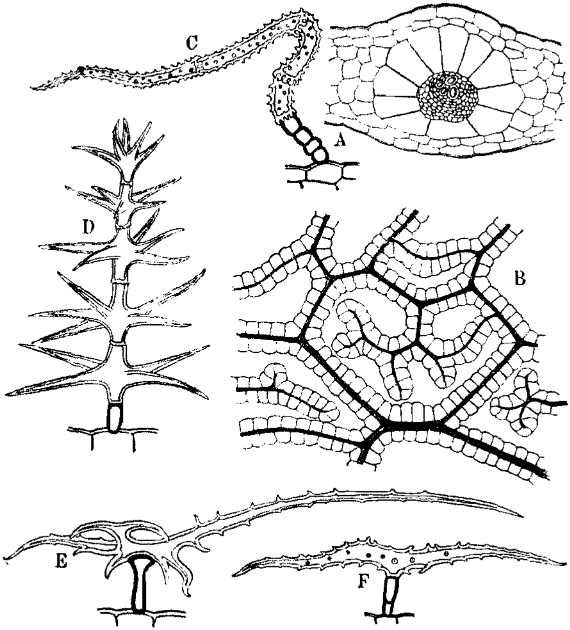

FIG. 156. A–B, Sheath round the vascular bundles in the veins of the leaf of *Amarantus Blitum*, L.: A, in transverse section; B, in surface-view. C–F, Forms of trichomes of the Amarantaceae: C, *Aerva lanata*, Juss.; D, *Cladothrix lanuginosa*, Nutt.; E, *Iresine Schaffneri*, Wats.; F, *Dicraurus leptocladus*, Hook. f.—Original.

Celosia, it has been shown to occur in the axis in species of the following genera by Regnault, Arcangeli, Nemnich and myself: *Deeringia*, *Celosia*, *Bosia*, *Chamissoa*, *Allmania*, *Amarantus*, *Acnida*, *Cyathula*, *Pupalia*. Crystalloids have been met with by Zimmermann in the chloroplasts of the leaf-tissue in *Achyranthes Verschaffeltii*, *Mogiphanes brasiliensis*, and a plant described as '*Aerva Sanguisorba*.'

Ordinary unicellular or uniseriate trichomes, which give rise to a crisp, woolly, or silky hairy covering, are widely distributed amongst the Amarantaceae. Capitate hairs with a unicellular or uniseriate stalk and a unicellular

spherical or ellipsoidal head are found on the veins on the lower side of the leaf in ***Amarantus***, and have also been observed by Nemnich in species of *Achyranthes*, *Acnida*, *Allmania*, *Alternanthera* and *Gomphrena*. There are numerous special forms of clothing hairs amongst the Amarantaceae; of these I may mention the following examples derived from my own investigations. *Ptilotus latifolius*, R. Br. has two-armed or many-armed trichomes, in which the stalk and the frequently long arms are composed of a row of cells with thin walls; the lowest cells of the stalk are short and have yellow walls. Characteristic uniseriate hairs, composed of a few short, basal cells with yellow walls, and several longer cells, of which the terminal one is pointed, are found in *Aerva lanata*, Juss. (Fig. 156, *C*), but not in *Aerva Monsonia*, Mart., where ordinary uniseriate hairs occur. The characteristic features presented by the trichomes of *Aerva lanata* are: (*a*) the presence of numerous small knobs [1] on the longitudinal walls of the longer cells; these knobs are not solid, but constitute papillose protuberances of the wall of the hair; and (*b*) the nature of the transverse walls in the upper portion of the hair; the surface of these walls is not plane, the margin being produced into papillae, so that the cells of the hair become firmly dovetailed with one another. If we imagine some of the papillae of the long cells of a hair in *Aerva lanata* as growing out into ray-cells at certain points, we should have candelabra-hairs like those of *Alternanthera*, *Cladothrix* (Fig. 156, *D*) and *Telanthera*. The following points of difference are shown by these hairs. In *T. frutescens*, Moq., the upper cells of the candelabra-hairs bear whorls of pointed branches, each whorl consisting of outgrowths from one of the cells immediately above the lower transverse wall, whilst in *Cladothrix lanuginosa*, Nutt. the branches radiate from the middle portion of the cell, the cells in question being cylindrical; in *Telanthera frutescens* we meet with the same small conical protuberances as in *Aerva lanata*, whilst in *Cladothrix lanuginosa* the nature of the transverse walls in the upper portion of the hair is the same as in *Aerva lanata*. According to Schleiden and De Bary, the candelabra-hairs of *Alternanthera spinosa* resemble those of *Telanthera frutescens*. The stellate hairs of *Iresine Pringlei*, Wats. may be regarded as a reduced form of candelabra-hair; they possess a uniseriate stalk and a terminal cell with three, four, or more rays. The hairy covering of a second species of *Iresine* (*I. Schaffneri*, Wats.) consists of transitional forms, some of which lead up to the trichomes of *Aerva lanata*, others to the two-armed hairs of *Dicraurus*. The commonest forms are uniseriate trichomes, in which the upper portion is provided with small-papillose protuberances, as in *Aerva lanata*, but the base of the terminal cell bears outgrowths in the form of a number of short rays. The remaining trichomes of *Iresine Schaffneri* are two-armed hairs with arms of unequal length; the terminal cell has thick walls, and exhibits small papillae all over its longitudinal walls, but bears still larger protuberances like rays just above the point of insertion of the stalk (Fig. 156, *E*). From hairs of this type it is not a great step to the two-armed trichomes of *Dicraurus leptocladus*, Hook. fil. (Fig. 156, *F*); here the terminal cell has equal arms, and its walls are likewise provided with small papillae.

The **petiole** contains an arc of isolated vascular bundles in the characteristic region in the species of *Celosia*, *Amarantus* and *Gomphrena* examined by Petit.

3. STRUCTURE OF THE AXIS. The **anomalous structure** of the stem [2]

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[1] Unicellular or uniseriate hairs with similar papillae are also figured by Martius, Nov. Gen. et Spec. plant. Brasil., vol. ii, Tab. 127 et seq., in species of *Hebanthe*, *Mogiphanes* and *Telanthera*, and by H. Schenck in *Hablitzia*; if I understand him rightly, Nemnich also observed them in species of *Achyranthes*, *Alternanthera* and *Gomphrena*.

[2] The anomalous structure has also been met with in the roots of the Amarantaceae.

has been demonstrated by Sanio, Regnault, De Bary, Solereder, Morot, H. Schenck, Houlbert and Nemnich in species of the following genera: *Deeringia*, *Celosia*, *Hermbstaedtia*, *Rodetia*, *Bosia*, *Chamissoa*, *Amarantus*, *Acnida*, *Pupalia*, *Psilotrichum*, *Aerva*, *Achyranthes*, *Telanthera*, *Alternanthera*, *Gomphrena*, *Froelichia*, *Hebanthe*. On the other hand the anomaly is wanting in the genus *Achatocarpus*, which has recently been transferred from the Amarantaceae to the Phytolaccaceae by Schinz and Autran, and according to my own observation also in the woody *Cladothrix lanuginosa*, the systematic position of which amongst the Amarantaceae had never yet been doubted. The mode of origin of the anomaly is the same as in the Nyctagineae; the secondary meristems develop in the parenchymatous pericycle, commonly on the inner side of small groups of sclerenchymatous fibres. In those cases in which there are successive meristematic rings, each producing a ring of vascular bundles, the latter are arranged in concentric circles. On the other hand, when there are only strips of meristem, arising irregularly, here and there, and each developing a single vascular bundle, whilst to the right and left meristematic strips of earlier

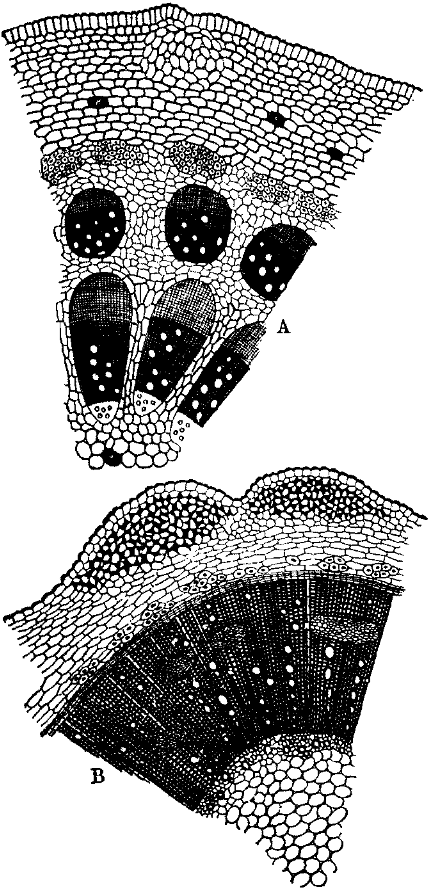

FIG. 157. Transverse sections through the axis of: A, *Bosia yerva mora*, L.; B, *Aerva scandens*, Wall.—Original.

origin are still active, the vascular bundles are irregularly arranged in the transverse section. It may be noted that in the first case (Fig. 157, *A*[1]) both the radial conjunctive tissue (simulating medullary rays), and the tissue occurring tangentially between the vascular bundles, is parenchymatous, whilst in the second case (Fig. 157, *B*[2]) the conjunctive tissue is prosenchymatous, groups of unlignified and lignified parenchyma being present only in connexion with the phloem-groups. Transitions between the two types are occasionally found (see *Hebanthe pulverulenta*, Mart. in H. Schenck's work). The prosenchymatous conjunctive tissue bears simple pits like the prosenchyma of the vascular bundles themselves. Medullary rays sometimes occur in the prosenchymatous conjunctive tissue. The vessels, which attain a diameter of ·2 mm. in the twining species of *Hebanthe*, have simple perforations. De Bary mentions the occurrence of apparently medullary vascular bundles[3] (with regard to this term see Nyctagineae) in species of *Celosia*, *Achyranthes* and *Amarantus*; in the species of the latter genus they are accompanied by true **medullary vascular bundles**. The angles, which are sometimes present on the stems of the Amarantaceae, consist of collenchyma (*Trichinium sericostachyum*, Nees, &c.). According to Regnault the development of cork takes place subepidermally in species of *Amarantus*.

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CHENOPODIACEAE.

(SUBORDO I, CHENOPODIEAE, BENTH. ET HOOK.[4])

1. Review of the Anatomical Features. The most striking anatomical feature in this Order is the anomalous structure of the stem, occurring in all Chenopodiaceae in which the growth in thickness is considerable. It consists in the appearance of pericyclic rings or strips of cambium, which originate and also lose their activity successively, forming secondary bundles and conjunctive tissue. Two extreme types exhibited by the transverse section of the stem may be distinguished: the first shows concentric zones of wood and bast; in the second there are vascular bundles embedded in prosenchymatous conjunctive tissue, and arranged in various ways, either

[1] The following species belong to this type: *Celosia argentea*, Moq., *Bosia yerva mora*, L. and *Chamissoa altissima*, H. B. K., as described in my 'Holzstruktur,' *Hebanthe holosericea*, Mart., according to H. Schenck, and *Rodetia Amherstiana*, Moq., according to Houlbert.

[2] The following species belong to this type: according to my 'Holzstruktur' *Deeringia baccata*, Moq., *Hermbstaedtia Caffra*, Moq., *Pupalia lappacea*, Moq., *Psilotrichum cordatum*, Moq., *Aerva scandens*, Wall. and *Telanthera ramosissima*, Moq., and according to Witte *Iresine elatior*, Rich.

[3] *Celosia argentea* and *Chamissoa altissima* also possess apparently medullary vascular bundles (see my 'Holzstruktur'). I will do no more than mention that there are further statements by Nemnich on this subject, as they do not appear to be quite reliable.

[4] The Suborder Baselleae of Bentham and Hooker is excluded from the following description, and will be treated separately after the rest of the Chenopodiaceae.

following a definite law or without regularity. Other features common to the members of the Order are as follows: the vessels usually have simple perforations only (exception *Axyris*); both the wood-prosenchyma of the vascular bundles and the prosenchymatous conjunctive tissue bear simple pits. True medullary rays occur in the species showing the first type of transverse section, but have not been observed in the prosenchymatous conjunctive tissue (in the second type). A sclerenchymatous pericycle is found in nearly all the

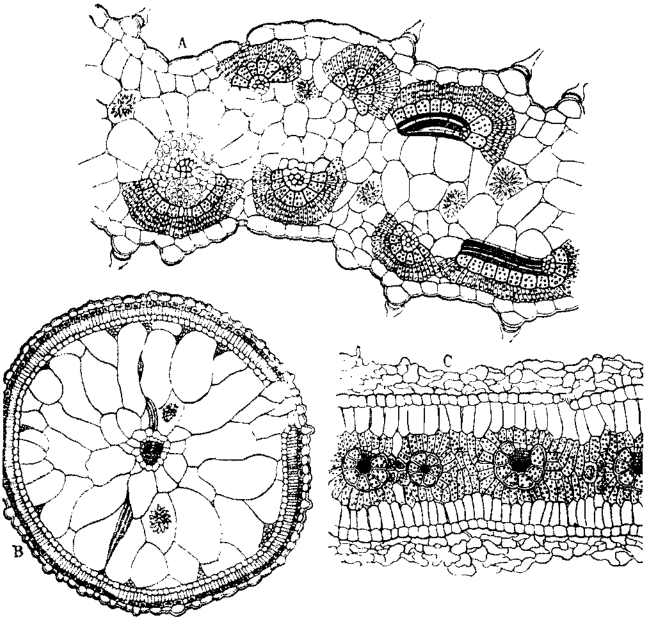

FIG. 158. Transverse sections through the leaves of. A, *Bassia muricata*, All.; B, *Salsola longifolia*, Forsk.; C, *Atriplex Halimus*, L.—After Volkens

members of the Order: it rarely consists of a closed sclerenchymatous ring, and is mostly composed of isolated groups of sclerenchymatous fibres. The formation of cork varies, and may be either superficial or internal; in the latter case it generally takes place in the pericycle. The following special anatomical features are found in the stem: the peculiar structure of the stem in certain Salsoleae and Salicornieae (which have a peripheral network of vascular bundles in the aqueous tissue, surrounding the usual vascular system of the axis); the occurrence of apparently medullary vascular bundles in certain cases (species of *Atriplex, Beta* and *Chenopodium*), and of true medullary bundles in *Acroglochin persicarioides*, Moq.; finally the presence of spiral tracheids

or spicular cells in the assimilatory parenchyma of the stem in certain species of *Arthrocnemum*, *Salicornia* and *Sarcobatus*. The most noteworthy features in the structure of the leaf are the absence of a definite type of stoma, and of typical spongy tissue, which has not been observed in any species. In spite of the xerophilous character of many species the cuticle rarely attains a considerable thickness, nor have mucilaginous epidermal cells been observed. On the other hand aqueous tissue and a covering of wax on the surface of the organs are present in certain species. The following anatomical features of the leaf are of value for special diagnosis: the varied mode of connexion between the assimilatory tissue and the vascular system of the veins (in some cases by means of a characteristic sheath, Fig. 158); the peripheral or central position of the aqueous tissue developed in the leaf (Fig. 158); and the transverse arrangement of the stomata, not uncommonly shown by narrow leaves (but occurring also on the axis). No internal secretory receptacles are present. Oxalate of lime is excreted chiefly in the form of clustered crystals and crystal-sand, rarely also in the form of solitary crystals. The hairy covering is very diverse. Glandular hairs are rare (*Camphorosma*, *Chenopodium*, Fig. 159, *L–O*), and always consist of a row of cells, of which the terminal cell or the uppermost cells are glandular. Water-storing bladder-like hairs (Fig. 159, *C–F*) are widely distributed; they have a unicellular or uniseriate stalk and a unicellular head, which varies in shape, being spherical, or sac-like, or sometimes differentiated like the terminal cell of a two-armed hair. The following types of clothing hairs are found: ordinary uniseriate trichomes; uniseriate trichomes with short basal cells and one or more longer cells, the latter being studded with cellulose-papillae (Camphorosmeae and Salsoleae of Volkens' classification, Fig. 159, *A*); two-armed hairs having a terminal cell with equal arms, and likewise provided with cellulose-papillae (*Petrosimonia*, Fig. 159, *B*); stellate hairs in which all the rays are branches of a single cell (*Grayia*, *Eurotia*, Fig. 159, *G–H*); stellate hairs with several uni- or multicellular rays (*Axyris*, Fig. 159, *J*); finally multicellular candelabra-hairs (*Corispermum*, Fig. 159, *K*, *Agriophyllum*).

2. Structure of the Leaf. The following description is mainly based on Volkens' statements.

The leaf-structure of the Chenopodiaceae shows a number of anatomical characters, which are correlated with the dry habitat of the members of the Order.

The **mesophyll** is in many cases differentiated into assimilatory and aqueous tissue. The assimilatory tissue is essentially composed of palisade-cells. Typical spongy tissue is absent in all the species examined by Volkens. According to Volkens the aqueous tissue shows three types of differentiation. In the first case (*Rhagodia Billardieri*, R. Br.) it forms several layers of palisade-like cells with thin walls beneath the upper epidermis of the leaf; it has not been determined whether these cells belong to the integumental tissue or not. In the second case (in species of the genera *Bassia*, *Kochia*, *Chenolea*, *Panderia*, *Kirilowia* and *Atriplex*) it forms the bulk of the mesophyll, whilst the palisade-parenchyma is relegated to the middle layers of the mesophyll (*Atriplex Halimus*, L., Fig. 158, *C*), or may even be confined to the immediate neighbourhood of the vascular bundles of the veins, the bundles then being always provided with special sheaths (*Bassia muricata*, All., Fig. 158, *A*). In the third case, which is met with in the usually terete leaves of the representatives of the Salicornieae, Suaedeae and Salsoleae, the chief part of the internal tissue of the leaf is composed of centrally placed aqueous tissue, which encloses the median vein together with its branches, lying at the periphery of the aqueous tissue; the latter is often (in species of *Halogeton*, *Salsola* and *Traganum*) surrounded by a special starch-sheath, this being followed

by a layer of palisade-parenchyma, and the latter by the epidermis (Fig. 158, *B*). Salts of calcium or other mineral salts are commonly present, dissolved in the contents of the aqueous cells.

The vascular bundles of the **veins** of the leaf are surrounded by special sheaths in some members of the Order (in the Camphorosmeae, Salsoleae, and many species of *Atriplex*, but not in the Chenopodeae, Corispermeae, Polycnemeae, Salicornieae, Suaedeae and most Atripliceae, according to Volkens [1]); the cells of these sheaths are distinguished by their size and shape, by the thickening of their walls, and by their contents (often including large chloroplasts). In flat leaves (e.g. in *Bassia muricata*, All., Fig. 158, *A*) these sheaths are found in direct connexion with the vascular bundles, and even in the finest ramifications of the veins they enclose the bundles, being either circular or hippocrepiform in transverse section; in more or less terete leaves (e.g. in species of *Halogeton*, *Salsola* and *Traganum*, Fig. 158, *B*) the sheath is external to the strongly developed aqueous tissue (see above), which encloses the fibrovascular system.

The **epidermis** of the leaf, so far as is known, consists of a single layer of cells. The outer wall rarely has a thick cuticle (epidermis of the leaf of *Agriophyllum*, and that of the branch of *Noaea*, according to Volkens). Gelatinization of the epidermis does not occur, but a granular coating of wax is sometimes found. **Stomata** are present throughout the epidermis of the leaf in the species [2] in which I examined the leaf-structure, and this is the case even in plants with flat leaves. In the narrow, terete, succulent leaves it is not a rare occurrence for the pairs of guard-cells to be parallel to one another, their pores being arranged transversely to the median vein of the leaf. A similar transverse arrangement of the stomata with reference to the longitudinal axis is also occasionally met with on the stem [3]. In the xerophilous species the stomata are commonly depressed below the surface. Strictly speaking, special subsidiary cells have not been observed in this Order, but in those cases in which the pairs of guard-cells show the abnormal arrangement mentioned above, and in which the ordinary epidermal cells of the leaf are also more or less distinctly elongated transversely to the midrib, there appear to be subsidiary cells placed parallel to the pore (on the leaf of *Camphorosma monspeliacum*, *Salsola Soda* and *Suaeda fruticosa*, and on the axis of *Salicornia*). It may be added that the narrow leaves of *Polycnemum arvense*, L. also possess stomata showing a parallel arrangement, but in this case the pore is parallel to the median vein of the leaf.

The **hairy covering** presents very diverse forms, some of which are characteristic of certain genera or groups of genera. Unicellular hairs are not present, but uniseriate hairs are widely distributed. Those on the leaf of *Chenopodium Botrys*, L., for example, consist of a rather large number of thin-walled cells, rendering the hair somewhat articulated. The uniseriate, simple hairs, which were pointed out by Volkens in species of *Bassia* and *Kirilowia* (Fig. 159, *A*) are especially characteristic; I also observed them in *Camphorosma* and *Echinopsilon*, and according to Volkens they are widely

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[1] The tribes referred to in connexion with Volkens' investigations are taken as defined in his classification in the Natürliche Pflanzenfamilien.

[2] These were: *Chenopodium glaucum*, L., *Atriplex hastata*, L., *Camphorosma monspeliacum*, L., *Corispermum hyssopifolium*, L., *Polycnemum arvense*, L., *Echinopsilon hyssopifolius*, Moq., *Suaeda fruticosa*, Forsk., *Salsola Soda*, L.

[3] The arrangement of the stomata as described above has been observed: I. on the leaves of *Camphorosma monspeliacum*, L., *Echinopsilon hyssopifolius*, Moq., *Halogeton alopecuroides*, Moq., *Salsola Kali*, L., *S. longifolia*, Forsk., *S. Soda*, L., *Suaeda fruticosa*, Forsk., *S. maritima*, Dum. and *Traganum nudatum*, Del., according to Brick, Volkens, Warming and my own observations; II. on the stem of *Suaeda fruticosa* (according to Georghieff) and of the *Salicornias* (according to Duval-Jouve).

distributed in the Camphorosmeae and Salsoleae. The hair is either seated on one prominent epidermal cell or between two such cells; it is composed of a basal portion consisting of one or a few cells, which have thin walls and are also often distinguished by their contents, and of a long pointed terminal portion consisting of one or a few cells, the walls of which are thick and more or less densely covered with small solid papillae. Another special form of trichome is seen in the two-armed hairs observed by Volkens in *Petrosimonia* (Fig. 159, *B*); the stalk in this case is formed by a few short cells, whilst the terminal cell is covered with papillae. Branched trichomes, which are of a similar

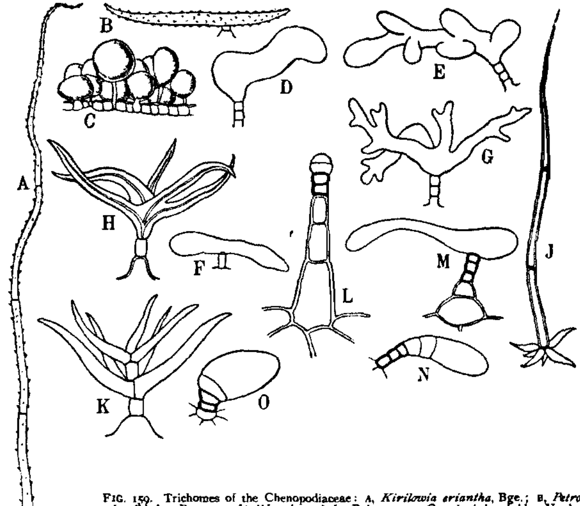

FIG. 159. Trichomes of the Chenopodiaceae: A, *Kirilowia eriantha*, Bge.; B, *Petrosimonia sibirica*, Bge.; C, *Atriplex leucoclada*, Boiss.; D–E, *Grayia polygaloides*, Hook. et Arn.; F, *Chenopodium album*, L.; G, *Grayia polygaloides*, Hook. et Arn.; H, *Eurotia ceratoides*, C. A. Mey.; J, *Axyris amarantoides*, L.; K, *Corispermum hyssopifolium*, L.; L, *Chenopodium Botrys*, L.; M–O, *C. ambrosioides*, L.—A–K after Volkens, the remainder original.

nature, and resemble stellate or candelabra hairs, have been met with by Volkens in two groups of allied genera (in *Grayia*, *Eurotia*, *Ceratocarpus* and *Axyris*, and in *Corispermum* and *Agriophyllum*). The stellate hairs of *Grayia polygaloides*, Hook. et Arn. (Fig. 159, *G*) and *Eurotia ceratoides*, C. A. Mey. (Fig. 159, *H*) have a short stalk of a few cells, and a stellately branched terminal cell, whilst those of *Axyris amarantoides*, L. (Fig. 159, *J*) consist of a long uniseriate hair bearing a few short ray-cells basally. The candelabra hairs of *Corispermum hyssopifolium*, L. (Fig. 159, *K*) and *Agriophyllum arenarium*, Bieb. have a uniseriate axis and unicellular rays.

The trichomes, to which Volkens gave the name of vesicular hairs, are especially characteristic of the Order, and give rise to the farinose surface described by systematic botanists. According to Volkens they are found in many species of *Chenopodium*, *Rhagodia*, *Monolepis*, *Atriplex*, *Exomis* and

Salsola, and they also occur in *Obione* (Warming), *Teloxys* and *Axyris* (Georghieff). The bladder-like hairs are of the capitate type, but have no secretory function. They consist of a unicellular or uniseriate stalk of variable length, and of a unicellular head, which is thin-walled, and stores up water. The head is mostly spherical in shape (*Atriplex leucoclada*, Boiss., Fig. 159, *C*, and *Chenopodium glaucum*, L.), but occasionally it is saccate. In the latter case the longitudinal walls of the head are sometimes provided with short protrusions (Fig. 159, *E*), thus constituting a transition to the stellate hairs of *Grayia* (see above); or the head is seated on the stalk in the same manner as the terminal portion of a one- or two-armed hair (Fig. 159, *D* and *F*). Biologically the bladder-like hairs serve for the storage of water, as Volkens has shown. When the water contained in them is used up, they collapse and form a membranous covering on parts of the plant where they have been present in large numbers.

True glandular hairs, secreting oil, have hitherto only been observed in *Camphorosma* and in species of *Chenopodium* belonging to the sections *Ambrina* and *Botrydium*. They are always uniseriate. In *Camphorosma* all the cells of the filamentous glandular hairs are secretory, with the exception of a few at the base; in *Chenopodium Botrys* (Fig. 159, *L*) the uppermost cells form an ellipsoidal glandular head, only slightly marked off from the stalk, which varies in length; in *C. ambrosioides*, L. (Fig. 159, *M–O*) there is an approach to the bladder-like type of hair, since the terminal cell is especially strongly developed (being sac-like, sometimes with two unequal arms), and is the principal or only seat of the secretory function.

Internal secretory receptacles have not been observed; but **oxalate of lime** is commonly excreted, and chiefly in the form of clustered crystals or crystal-sand. Octahedral or prismatic crystals, which apparently belong to the tetragonal system (in the leaf of *Echinopsilon hyssopifolius* and *Camphorosma monspeliacum*), are rare, and so are monoclinic crystals (Volkens). Among the species in which I examined the leaf-structure, clustered crystals only are present in *Atriplex hastata*, *Corispermum hyssopifolium*, *Polycnemum arvense*, *Echinopsilon hyssopifolius* and *Salsola Soda*; in *Chenopodium glaucum* and *Camphorosma monspeliacum* there are cells with clustered crystals, others containing coarsely granular crystal-sand besides clustered crystals, and others with coarse crystal-sand alone; *Chenopodium Botrys* has cells with coarsely granular crystal-sand, while in *Suaeda fruticosa* it is more finely granular. Crystal-sand has also been observed in the stem in species of the genera *Ambrina*, *Anabasis*, *Camphorosma*, *Echinopsilon*, *Exomis*, *Haloxylon*, *Salsola* and *Traganum* as stated in my 'Holzstruktur.' In the succulent leaves of *Salsola longifolia*, Forsk., *Halogeton alopecuroides*, Moq., and *Traganum nudatum*, Del., the clustered crystals occupy, according to Volkens, a peculiar position. In these species a loose layer of colourless, roundish cells is intercalated between the epidermis of the leaf and the palisade-tissue; the majority of these cells, or all of them, contain each a single clustered crystal; Volkens regards this sheath of crystals as a protective arrangement against the attacks of snails.

In the species of the genera *Atriplex*, *Blitum* and *Chenopodium* examined by Petit, the fibrovascular system of the **petiole** is formed by isolated vascular bundles, which are arranged in an arc or ring.

3. Structure of the Axis. Those Chenopodiaceae which exhibit considerable growth in thickness are characterized by the same **anomalous structure** of the axis, as occurs in the Nyctagineae and Amarantaceae. The following statements regarding the course of development of this anomaly are quoted from Morot's work: secondary rings or arcs of meristem (the latter anastomosing reticulately) arise in centrifugal succession in the pericycle (internally to the bast-fibres, where these are present) and produce

secondary vascular bundles as well as conjunctive tissue of varying structure. The xylem-portions of these secondary vascular bundles always arise on the inner, the bast-portions on the outer side of the secondary meristem. The appearance of a transverse section of the axis differs, according to the nature of the conjunctive tissue and that of the meristem. In the one case (e.g. in *Camphorosma* and *Echinopsilon*) rings of woody tissue alternate, in the radial direction, with rings of thin-walled tissue; the former are traversed by lignified or thin-walled medullary rays of varying breadth, the broader rays sometimes separating the xylem-groups of the vascular bundles of the same ring from one another; the other rings of tissue consist of the phloem-portions of the vascular bundles together with thin-walled, parenchymatous conjunctive tissue, which is present in variable amount. In the second case, which is connected with that first described by means of intermediate types, and occurs in the majority of the Chenopodiaceae, the vascular bundles are embedded in a prosenchymatous interfascicular tissue, and exhibit a concentric, spiral, or irregular arrangement. In this case the xylem-groups of the vascular bundles coalesce with the conjunctive tissue; they are only distinguishable owing to the arrangement of their vessels in groups opposite the bast-portions. The latter vary in size, and are sometimes (*Halostachya caspia*, C. A. Mey.) remarkably small; a group of lignified or unlignified parenchymatous conjunctive tissue is commonly associated with them.

In a transverse section of the stem **medullary vascular bundles** also appear in certain members of the Order, but these are rarely (in *Acroglochin persicarioides*, Moq., according to Georghieff) true medullary bundles. In most cases [1] their development shows that they are the normal leaf-trace bundles, and only apparently medullary; for the first secondary meristem produces pith-like tissue external to them before proceeding to the formation of the secondary bundles.

The **leaf-trace bundles** sometimes possess considerable growth in thickness, and thus delay the appearance of the anomalous growth (*Camphorosma* and *Echinopsilon*, as also *Blitum virgatum*, *Chenopodium murale* and *C. hybridum*, according to De Bary, *Kochia prostrata* according to Georghieff). It may be added here that in *Halostachys caspia*, C. A. Mey., 5–8 zones of growth correspond to one period of vegetation, and consequently a decrease in the size of the lumina of the vessels from within outwards may be recognized in the region of these five zones, as in an annual ring.

The following statements regarding the distribution of the **anomaly** in the Order are derived from the descriptions given by the various investigators (Gernet, Regnault, De Bary, Morot, Solereder, Volkens, Georghieff). Probably the anomaly occurs in all species having considerable growth in thickness; at any rate no well established exception [2] in this respect is yet known. Only those genera and species which exhibit little or no growth in thickness have stems with normal structure. According to Volkens, *Oreobliton*, *Aphanisma* and *Monolepis* are examples. In *Blitum Bonus Henricus*, *Beta trigyna* and *Hablitzia tamnoides* the stem is normal in structure only in its upper portion according to Georghieff. In the following genera the anomaly has been described in the literature (the sequence is that of Bentham and Hooker's classification): *Acroglochin*, *Hablitzia*, *Rhagodia*, *Monolepis*, *Chenopodium*, *Teloxys*, *Beta*, *Spinacia*, *Exomis*,

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[1] In many herbaceous species of *Atriplex*, *Beta*, *Chenopodium* and *Obione*, according to Georghieff (see also De Bary).

[2] The two exceptions which Georghieff mentions (*Camphorosma monspeliacum*, L. and *Grayia Sutherlandi*, Hook. et Arn.') are non-existent; cf. Volkens, loc. cit.

Atriplex, Grayia, Eurotia, Axyris, Camphorosma, Corispermum, Agriophyllum, Chenolea, Kochia, Halostachys, Halocnemon, Arthrocnemum, Salicornia, Suaeda, Traganum, Cornulaca, Haloxylon, Salsola, Noaea, Anabasis, Halogeton and *Sarcobatus*.

The following facts may be noted regarding the detailed anatomical structure of the axis. The stems of the herbaceous forms very commonly possess subepidermal bundles of collenchyma, which project as ribs. The portions of the epidermis adjoining the collenchymatous bundles externally often consist of elongated cells (e.g. in *Salsola Kali*, L.), whilst the intervening epidermal cells are approximately isodiametric in surface-view. The outer portion of the primary cortex sometimes (e.g. in species of *Corispermum, Salsola, Suaeda*, &c.) contains palisade-tissue. In most cases the outer limit of the pericycle is formed by groups of sclerenchymatous fibres, so that the occurrence of a sclerenchymatous pericycle may be considered as an ordinal character in the Chenopodiaceae, as is held by Georghieff. The sclerenchyma, however, rarely attains a strong development; thus in *Blitum Bonus Henricus*, for instance, only weak strands of collenchyma are present. According to Georghieff and Volkens the place of origin of the cork varies. In *Camphorosma* and its immediate allies the subepidermal cell-layer becomes the phellogen (Volkens); in *Kochia prostrata*, Schrad. the cork arises in the primary cortex (Georghieff); finally in the Atripliceae, Salicornieae, Suaedeae and Salsoleae [1], according to Volkens, the cork cambium is constituted by a layer of the pericycle, which lies immediately to the interior of the groups of sclerenchymatous fibres, where these occur. The prosenchymatous conjunctive tissue usually has thick walls, and always bears simple pits, and its cells may be arranged in radial series, or irregularly; medullary rays, such as occur in the Nyctagineous genus *Pisonia*, have not been observed in this tissue, which in many cases cannot be distinguished from the wood-prosenchyma of the vascular bundles, since the elements of the latter tissue also have simple pits. True spiral tracheae (primary vessels) only occur in the innermost vascular bundles, i. e. in the leaf-traces. The pitted vessels of the **wood** generally possess a diameter of ·015–·045 mm.; the twining species *Hablitzia tamnoides* has vessels with wide lumina. The perforations of the vessels are as a rule simple. Scalariform perforations, 'with very oblique, almost longitudinal bars,' have only been recorded in *Axyris amarantoides* by Georghieff. Spiral thickening of the vessel-wall is very widely distributed, and sometimes occurs in all the pitted vessels, but in most cases only in those with narrow lumina; it has been observed in certain species of *Atriplex, Camphorosma, Eurotia, Halocnemon, Halostachys, Haloxylon, Kochia, Noaea, Rhagodia* and *Suaeda* (for details see my 'Holzstruktur' and Georghieff's work).

Certain genera of the tribes Salicornieae and Salsoleae require a special description. In the stem, as in the leaves of these genera (see above), strongly developed **aqueous tissue** is present; it surrounds the vascular system, and is in its turn enclosed by a sheath of palisade-tissue, and this again by the epidermis; the latter is sometimes (as in *Anabasis aphylla*, L., *Brachylepis eriopoda*, Schrenk, &c.) strengthened by hypoderm. The aqueous tissue is enveloped by a characteristic network of vascular bundles closed on all sides; the xylem-groups of these bundles point inwards in the normal way in the Salicornieae investigated by Dangeard, but are directed outwards in the Salsoleae examined by the same author. It may also be noted that the same characteristic sheath of collecting-cells as occurs in the leaves has been observed between the palisade and aqueous tissue of the stem but in the Salsoleae only.

[1] Again these groups are to be taken as defined in Volkens' revision of the Chenopodiaceae.

The features in question have been recorded in the following cases by Dangeard: amongst the Salicornieae in species of *Halostachys*, *Halocnemon*, *Arthrocnemum* and *Salicornia*; amongst the Salsoleae in species of *Ofaiston*, *Noaea* and *Anabasis* (with *Brachylepis*); cortical vascular bundles with inverse orientation were also found in species of *Horaninovia*, *Caroxylon*, *Girgensohnia*, *Halimocnemis* and *Halanthium*. See also Volkens' work, with regard to species of *Cornulaca*, *Haloxylon* and *Anabasis*. The stem of *Salsola Kali*, L. exhibits the layer of palisade, the characteristic sheath and the aqueous tissue, but the network of bundles is wanting (Brick).

In certain species of *Salicornia* and *Arthrocnemum* the palisade-tissue of the stem contains sac-like tracheids with wide lumina and strengthened by means of a spiral band; the longitudinal axes of these elements lie radially. They are found in *Salicornia fruticosa*, *S. patula*, *S. peruviana*, *S. sarmentosa*, *S. virginica* and *Arthrocnemum ambiguum*, whilst they are only slightly developed in *S. Emerici*, and are wanting in *S. herbacea*, *Arthrocnemum arbuscula*, *A. capsicum* and *A. indicum* (Duval-Jouve, Dangeard). In *Salicornia macrostachya* their place is taken by spicular cells, which are elongated in the same direction, and slightly branched, especially at their apices. Similar 'stereides' occur in *Arthrocnemum* and *Sarcobatus*, according to Volkens.

The **root** exhibits the same anomalous structure as the stem. For systematic purposes it is an important fact that the anomaly may be demonstrated in the root of species in which it does not appear in the stem, owing to the small amount of growth in thickness in the latter (*Blitum Bonus Henricus*, *Beta trigyna*, *Hablitzia tamnoides*, according to Georghieff).

Literature: Unger, Bau u. Wachst. d. Dicotyledonenst., St. Petersburg, 1840, pp. 104–8, Tab. xiii–xiv.—Basiner, Kirghisensteppe, in Baer u. Helmersen, Beitr. z. Kenntn. d. russ. R., Bd. xv, 1848, p. 93.—Schacht, Pflanzenz., 1852, p. 283 and Tab. xv.—Gernet, Holzk. einiger Ch., Bull. Soc. imp. Natural. de Moscou, t. xxxii, 1859, pp. 164–88 and Tab. ii.—Regnault, Cyclospermées, Ann. sc. nat., sér. 4, t. xiv, 1860, pp. 133–9 and pl. viii.—Sanio, in Bot. Zeit. 1863, p. 410 and 1864, p. 226.—A. Weiss, Pflanzenhaare, 1867, Fig. 198.—Duval-Jouve, Salicorniées, Bull. Soc. bot. de France 1868, pp. 132–40 and pl. 1.—Van Tieghem, Symm. de struct., Ann. sc. nat., sér. 5, t. xiii, 1871.—Martinet, Org. de sécrét., Ann. sc. nat., sér. 5, t. xiv, 1872, p. 139 and pl. 8.—De Bary, Vergl. Anat., 1877.—Droysen, Anat. etc. d. Zuckerrübe, Diss., Halle a. S., 1877, 37 pp.—Areschoug, Blad. anat., Minnesskrift Lund 1878, p. 117 et seq. and Tab. ix.—De Vries, Wachstumsgesch. d. Zuckerrübe, Landwirtsch. Jahrb. v. Thiel, Bd. viii, 1879, p. 417 et seq. and Tab. vi.—Hultberg, *Salicornia*, Acta Lund., vol. xviii, 1881–2, 51 pp. and 5 Tab.—Batalin, *Salicornia herbacea*, Bull. congrès de bot. et d'hort. à St. Pétersbourg, 1884, pp. 219–33; Just 1884, I, p. 313.—Pichi, *Beta vulgaris*, var. *saccharifera*, Nuov. Giorn. bot. Ital., vol. xvi, 1884, pp. 262–81.—Volkens, Standort u. anat. Bau, Jahrb. Berlin. Gart. 1884, p. 37 et seq.—Morot, Péricycle, Ann. sc. nat., sér. 6, t. xx, 1885, especially p. 277 et seq.—Hérail, Tige des Dicotyl., Ann. sc. nat., sér. 7, t. ii, 1885, pp. 245–6.—Solereder, Holzstr., 1885, pp. 217–19.—Georghieff, Vergl. Anat. d. Ch., Bot. Centralbl. 1887, ii, p. 117 et seq. and Tab. iv–vii and 1887, iii, p. 23 et seq.—Lohrer, Wurzel, in Wigand, Bot. Hefte, ii, 1887, pp. 30–3 and Tab. ii.—Petit, Pétiole, Mém. Soc. sc. nat. et phys. de Bordeaux, sér. 3, t. iii, 1887, pp. 236–9 and pl. ii.—Volkens, Aegypt.-arab. Wüste, 1887, pp. 138–42 and Tab. xi, xii and xv.—Brick, Balt. Strandpfl., Schrift. naturf. Gesellsch. in Danzig, Bd. xvii, 1. Heft, 1888, pp. 136–43 and Tab. ii.—Dangeard, Struct. des Salicornieae et des Salsolaceae, Bull. Soc. Linn. de Normandie, sér. 4, t. ii, Caën, 1888, pp. 88–95; see also Bull. Soc. bot. de France 1888, pp. 157 and 197 et seq.—Van Tieghem, in Ann. sc. nat., sér. 7, t. viii, 1888, p. 70.—Warming, Fra Vesterhavskystens Marskegne, Vidensk. Meddelels. naturh. Foren. i Kbhvn. 1890, pp. 214 et seq., 221 and 225.—Arcangeli, Strutt. delle foglie dell' *Atriplex*, Nuov. Giorn. bot., vol. xxii, 1890, pp. 426–30.—Benecke, Nebenz. etc., Bot. Zeit. 1892, p. 574.—Volkens, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 a, 1892, pp. 39–44.—H. Schenck, Anat. d. Lianen, 1893, pp. 48–9 and 251.—Houlbert, Bois dans les Apétales, Thèse, Paris, 1893, pp. 70–1.—Herbst, Markstr., Bot. Centralbl. 1894, i, p. 295.—Russell, Climat méd., Ann. sc. nat., sér. 8, t. i, 1895, p. 336 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl. 1897, iv, p. 63 et seq.—Warming, Halofyt Stud., K. Danske Vid. Selsk. Skr. 1897, pp. 190 et seq., especially 215 and 229 et seq.—[Fron, Racine des *Suaeda* et des *Salsola*, Compt. rend., t. cxxv, 1897, p. 366 and Struct. spiralée des rac. de cert. Ch., loc. cit., t. cxxvii, 1898, p. 563.]

BASELLACEAE.

The limits of this small Order, which was established by Moquin-Tandon in DC., Prodr., vol. xiii. 2, coincides with those of Subordo II Baselleae in the classification of the Chenopodiaceae in Bentham and Hooker's Genera

Plantarum. The elevation of this Suborder to the rank of an Order and its separation from the Chenopodiaceae is also warranted on anatomical grounds. Neither the stem nor the root of the Basellaceae exhibits the anomaly found in the Chenopodiaceae, whilst on the other hand intraxylary soft bast occurs. Other noteworthy features for the diagnosis of the Order are the structure of the stomatal apparatus (which belongs to the Rubiaceous type) and the sclerenchymatous pericycle in the stem. Oxalate of lime is excreted in the form of clustered crystals, and more rarely in that of solitary tetragonal crystals. Mucilaginous sap, which can be drawn out into threads, has been observed in the leaves and cortex of certain members of the Order; it is due to the occurrence of spherical mucilage-cells.

I have made a detailed examination of the **leaf-structure** in *Basella rubra*, L., *Boussingaultia baselloides*, H. B. K. and *Anredera spicata*, Pers. Trichomes are not present. Both sides of the leaf are provided with stomata, which are accompanied by two or more subsidiary cells, arranged parallel to the pore. Large, spherical mucilage-cells, in which the mucilage apparently originates from the membrane and does not belong to the cell-contents, are only found in the mesophyll in the species of *Anredera* and *Boussingaultia*. Clustered crystals of oxalate of lime are present in the leaf-tissue of the three species investigated; in *Basella rubra* there are also prismatic or octahedral crystals of the same salt, and in the dried leaf of *Anredera spicata* yellowish sphaero-crystalline masses of unknown chemical composition.

The **petiole** in *Basella rubra* contains two large, nearly median vascular bundles, adjoined on either side by smaller bundles; in *Boussingaultia baselloides* there is an arc of wood and bast (Petit).

The structure of the **axis** has been investigated by Morot in *Basella rubra*, *Boussingaultia baselloides* and *Ullucus tuberosus*, and by me in *Basella rubra* and *Anredera spicata*. In all these species there is a sclerenchymatous pericycle, which is weakly developed in *Ullucus tuberosus*, but strongly developed and continuous in *Anredera spicata*; in *Boussingaultia baselloides* it is broken up. The vascular bundles are of different sizes, smaller strands being intercalated between the larger; the bundles are isolated and arranged in a ring. The larger bundles possess intraxylary soft bast, which is developed to a variable extent and only arises secondarily, according to Morot. The diameter of the vessels is large (reaching ·2 mm. or more) in *Anredera*, and probably also in the other twining species; the perforations are simple. The formation of cork takes place in the outermost cell-layers of the primary cortex in *Boussingaultia baselloides*.

Literature: Strasburger, Spaltöffn., Pringsheim Jahrb. 1866–7, p. 316 and Tab. xxxviii.—Morot, Anat. d. B., Bull. Soc. bot. de France 1884, pp. 104–7.—Georghieff, in Bot. Centralbl. 1887, ii, pp. 371–3.—Petit, Pétiole, Mém. Soc. sc. nat. et phys. de Bordeaux, sér. 3, t. iii, 1887, p. 238 and pl. i. —Volkens, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 a, 1893, p. 125.

PHYTOLACCACEAE.

1. Review of the Anatomical Features. In its anatomy this Order only possesses a few distinctive characters common to all its members. Such are the absence of external glands and of special internal secretory receptacles, the simple perforations of the vessels and the superficial development of the periderm. On the other hand the type of stoma and the nature of the pitting in the wood-prosenchyma vary within the limits of the Order. The Rubiaceous type is well marked only in certain genera (*Ledenbergia*, *Monococcus*, &c.); in other cases the stoma is surrounded by a relatively large number of epidermal cells exhibiting no special arrangement. The

wood-prosenchyma bears simple pits in the Rivineae (excl. *Microtea*) and Euphytolacceae, but in the Gyrostemoneae, *Microtea* and the anomalous genus *Stegnosperma*, the pits in this tissue have narrow though distinct borders. The pericycle is sclerenchymatous, containing a composite and continuous sclerenchymatous sheath (e.g. in *Codonocarpus, Gallesia, Phytolacca, Seguieria*), or isolated groups of bast-fibres, or isolated fibres. Secondary hard bast has not been observed. In a number of genera belonging to the tribes Rivineae and Euphytolacceae the structure of the stem or root is anomalous (stem and root of *Phytolacca*, stem of *Ercilla, Gallesia* and *Seguieria*, root and (?) stem of *Anisomeria*); the anomaly consists in the formation of successive secondary rings of vascular bundles in the pericycle. Oxalate of lime never occurs in the form of the ordinary solitary or clustered crystals. The Rivineae (excluding *Microtea*) are distinguished by possessing styloids; in the Euphytolacceae and the anomalous genus *Agdestis* raphide-sacs are characteristic, and in the Gyrostemoneae the absence of oxalate of lime; the anomalous genus *Stegnosperma* possesses sphaerites. Raphides and styloids not uncommonly give rise to pellucid dots in the leaf. The hairy covering consists of simple uniseriate hairs. The following special anatomical features of the Order may be shortly referred to at this point: the occurrence of hypoderm on the upper side of the leaf (*Gallesia Gorazema*, Moq.); gelatinization of epidermal cells (species of *Codonocarpus* and *Gyrostemon*) and more rarely of internal cells in the tissue of the leaf; medullary vascular bundles in the stem (*Phytolacca dioica*, L.); and sacs, crowded with numerous crystals of varied shape (species of *Gallesia* and *Monococcus*).

2. Structure of the Leaf [1]. This is bifacial in most members of the Order, more rarely centric (in *Gallesia Gorazema*, Moq., *Codonocarpus australis*, Cunn., *Gyrostemon ramulosus*, Desf., and according to Schulze *Didymotheca thesioides*). When the leaf is centric the mesophyll either consists of palisade-tissue throughout (*Gallesia Gorazema*), or the middle of the leaf contains aqueous tissue (*Gyrostemon ramulosus*). The **epidermal cells** have straight or undulated lateral walls. Gelatinization of the epidermis is mentioned by Blenk as occurring in *Codonocarpus australis* and *Gyrostemon ramulosus*; cells with mucilaginous membranes are also found in a subepidermal position in the larger veins of the leaf in *Codonocarpus australis*, and in the central aqueous tissue of *Gyrostemon ramulosus*. In the species of *Petiveria* the epidermal cells contain chlorophyll (Schulze). A **hypoderm**, composed of two layers of rather large cells, is developed on the upper side of the leaf in *Gallesia Gorazema*. The **stomata** are either confined to the lower side of the leaf, or (in *Phytolacca dioica*, L., and according to Schulze especially in species of *Microtea, Codonocarpus* and *Didymotheca*) occur on both surfaces. According to my own observations those of *Codonocarpus* and *Phytolacca* are always surrounded by a number of ordinary epidermal cells exhibiting no special arrangement, whilst in *Rivina* and *Gallesia* stomata belonging to the Rubiaceous type also occur, the latter being the only type present in *Ledenbergia* and *Monococcus*. Schulze describes the Rubiaceous type as occurring in *Petiveria, Monococcus* and *Gallesia*, and for the most part in *Ledenbergia* and *Mohlana*. In the larger **veins** there is generally no sclerenchyma accompanying the vascular bundles, but in those of *Gallesia Gorazema* a sclerenchymatous ring is developed.

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[1] The structure of the leaf and axis has recently been examined in detail by Schulze. In his work the following genera were investigated: *Rivina, Ledenbergia, Mohlana, Petiveria, Microtea, Monococcus, Seguieria* and *Gallesia* (Tribe Rivineae); *Phytolacca, Ercilla* and *Anisomeria* (Tribe Euphytolacceae); *Didymotheca, Codonocarpus* and *Gyrostemon* (Tribe Gyrostemoneae); and the anomalous genera *Stegnosperma* and *Agdestis*.

The mode of excretion of **oxalate of lime** differs in the different tribes. The genera ***Rivina, Mohlana, Petiveria*** and ***Seguieria*** (according to Blenk), *Gallesia* (according to Radlkofer), ***Ledenbergia*** and ***Monococcus*** (according to Schulze), and ***Villamilla*** (***V. octandra***, Hook. f.) all belonging to the Tribe Rivineae, possess styloids (sometimes having the shape of a swallow's tail); in ***Microtea***, which is included in the same tribe by Bentham and Hooker, oxalate of lime appears to be wanting (according to my own investigation of the axis and leaf in *M. maypurensis*, Don, and according to Schulze). The genera ***Phytolacca***, ***Ercilla*** and ***Anisomeria***, belonging to the Tribe Euphytolacceae, contain raphides, according to Blenk; the same form of crystal also occurs in the anomalous monotypic genus *Agdestis*, according to Schulze. In the Gyrostemoneae (*Didymotheca, Codonocarpus, Gyrostemon*) oxalate of lime has not been observed. The anomalous genus *Stegnosperma* is characterized by possessing large sphaerites of oxalate of lime (Schulze). It may be added that the styloids and bundles of raphides occur both in the mesophyll and in the parenchymatous tissues and bast of the axis; those in the mesophyll are arranged either parallel or at right angles to the leaf-surface, and in the latter case commonly give rise to transparent dots. The styloids often attain very considerable dimensions. In *Gallesia Gorazema* and *Monococcus echinophorus*, F. v. Müll., the styloids are accompanied by special crystal-sacs in the mesophyll and veins of the leaf (according to my own observations), and in the former species similar sacs occur in the primary cortex of the axis; they are filled with numerous, rather small crystalline bodies, the shape of which varies, being either shortly prismatic or rounded (Fig. 160). In the same way small crystals, resembling styloids, are found in considerable numbers side by side with well-developed styloids in certain cells of the bast of *Rivina humilis*, L., and in the leaf of *Villamilla octandra*. Zimmermann states that nuclear crystalloids occur in the cells of the mesophyll in *Rivina humilis* and *Ledenbergia rosea-aenea*, and in the former species in the epidermis of the leaf also. Kruch has recorded crystalloids, occurring free in the cell-sap, in the apical region of the leaf in *Phytolacca abyssinica*, and according to the same author peculiar spherical bodies containing proteid and varying as to the nature of their surface, occur in cells of the apex of the leaf in *P. icosandra*. Special internal secretory receptacles [1] are absent.

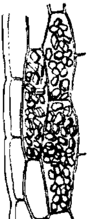

FIG. 160. Crystal-sacs in the veins of the leaf of *Gallesia Gorazema*, Moq.—Original.

The **hairy covering** consists only of simple uniseriate hairs; glandular hairs are not present.

In *Phytolacca decandra*, L., a transverse section of the **petiole** in the characteristic region shows an arc of three isolated vascular bundles, with smaller bundles adjoining them towards the margins of the petiole.

3. STRUCTURE OF THE AXIS. Some of the genera belonging to the Tribes Rivineae and Euphytolacceae are distinguished by having an **anomalous stem-structure**, which consists in the appearance of successive rings of vascular hundles in the pericycle. This anomaly has long been known to occur in species of ***Phytolacca*** (***P. abyssinica***, Hoffm., ***P. acinosa, P. decandra***, L., ***P. dioica***, L., ***P. icosandra***, L.), where it is found not only in the stem, but also in the root (Avetta). Krüger also observed it in a piece of the branch of

[1] Schulze correctly describes brown, tanniniferous cells as occurring in the mesophyll of *Gallesia Gorazema*; but his statement regarding the occurrence of subepidermal secretory cells (=the gelatinized portions of the membrane of mucilaginous epidermal cells) in the leaf of *Codonocarpus australis* and in a plant with linear leaves, described as '*Gyrostemon australis*,' is incorrect.

Ercilla volubilis 2 cm. in thickness, and I have met with it in *Seguieria floribunda*, Benth. and *S. longifolia*, Benth., to which on Schulze's authority we may add *S. americana* [1]. According to Schulze this anomaly is also found in *Gallesia Gorazema*, Moq. and *Anisomeria drastica*, Moq.; I can confirm these statements in the case of the stem of the former species, and at any rate as regards the root of the latter. Transverse sections of sufficiently thick branches of the above-mentioned species of *Phytolacca, Ercilla, Seguieria* and *Gallesia* show alternating concentric rings of wood and bast. The innermost ring, which alone contains primary spiral tracheae, consists of the leaf-traces. In the young branch a parenchymatous pericycle adjoins the bast-groups of the leaf-traces, and this is followed by a composite and continuous ring of sclerenchyma, which bounds the primary cortex on the inner side. The parenchymatous pericycle is the seat of the new formations, and in it there arises a meristem, which before giving rise to a secondary ring of vascular bundles, produces parenchyma on its inner side, part of this tissue becoming lignified. Hence each secondary ring commences with a zone of parenchymatous tissue, the amount of which varies. The medullary rays between the vascular bundles of each ring are broad in most cases, and are generally lignified; sometimes (*Gallesia Gorazema*) even the rays traversing the zones of bast are lignified, at least in the internal rings of growth. The greater part of the napiform root of *Anisomeria drastica* consists of large parenchymatous cells containing raphides, as I found on examining the slices of the root which accompany Lechler's herbarium-material; the centre of the root is occupied by the primary vascular tissue, but this is split up by secondary dilatation; in the ground-tissue adjoining this central mass of tissue one finds several concentric circles of isolated vascular bundles, in which each xylem-group is marked by an elongated row of vessels with rather narrow lumina, the groups of bast being clearly developed [2]. It may also be noted that *Phytolacca dioica* has medullary vascular bundles, the structure of which is concentric according to Nägeli and Douliot, the phloem being central. It remains to be determined by future investigation whether the other genera of the tribes Rivineae and Euphytolacceae will not also prove to have anomalous structure in the axis, when sufficiently old material is examined. From Regnault's description, which however is not quite clear, it appears that *Rivina humilis*, L. possesses the same anomaly as is found in *Phytolacca*. Schulze observed the commencement of anomalous growth in the root of *Petiveria*. In *Ledenbergia rosea-aenea*, on the other hand, anomalous growth in thickness seems to me to be out of the question, since I found branches almost 2 cm. in diameter exhibiting normal structure.

The structure of the **wood** has been examined by me in species of *Rivina, Microtea, Seguieria, Gallesia, Phytolacca, Ercilla, Anisomeria, Codonocarpus* and *Gyrostemon*, and also by Schulze. The size of the lumina and the mode of arrangement of the vessels vary (maximum diameter = ·03–·15 mm.); the size of the borders of the pits in the vessels is also variable (diameter reaching ·009 mm. in *Phytolacca*). Spiral thickening of the pitted vessels has been observed in *Anisomeria drastica*. The perforations of the vessels are simple in all cases. Where the vessel-wall is in contact with parenchyma, it either bears bordered pits only (*Seguieria, Codonocarpus, Gyrostemon*), or bordered and simple pits (*Gallesia, Phytolacca*). Broad medullary rays are found (for example) in *Gallesia* and *Phytolacca*; in *Seguieria* and *Codonocarpus* the rays are from one to three cells in breadth; in *Anisomeria* distinct ray-parenchyma

[1] The anomalous structure of this plant is incorrectly interpreted in Möller's work (loc. cit. 1876).

[2] Further investigation is required to determine whether this anomaly also occurs in the stem of *Anisomeria drastica*, as stated by Schulze, or whether woody tissue, some of which is unlignified, has not been mistaken for phloem; I did not find the anomaly in herbarium-material, even in thick branches.

is not present. The wood-prosenchyma is characterized by having simple pits in the Rivineae (excluding *Microtea*) and Euphytolacceae so far as investigated, but in the Gyrostemoneae, *Microtea*, and according to Schulze also in *Stegnosperma* it is provided with small but distinct bordered pits. The wood-fibres of *Rivina humilis* are septate in some places.

The following statements regarding the structure of the **cortex** are based on my own examination of *Rivina humilis, Ledenbergia rosea-aenea, Seguieria longifolia, Gallesia Gorazema, Phytolacca dioica* and *Codonocarpus australis*, and on Schulze's description. In *Rivina humilis* and *Ledenbergia rosea-aenea* the pericycle contains small isolated bundles of sclerenchymatous fibres, while in the rest of the species examined by me there is a composite and continuous ring of sclerenchyma; Schulze states that bast-fibres occur in the pericycle in all cases, the fibres being sometimes accompanied by stone cells. Secondary hard bast has not been observed. In *Phytolacca dioica* the primary cortex shows a strong development of collenchyma in its outer portion, whilst in *Codonocarpus australis* it contains a few sclerosed parenchymatous cells; in *Seguieria longifolia* the cortex is bounded by an epidermis composed of cells elongated like palisade-tissue. The formation of cork takes place in the subepidermal cell-layer (*Ledenbergia, Phytolacca* and *Codonocarpus*, according to my own observation; *Petiveria, Seguieria, Gallesia, Phytolacca* and *Gyrostemon*, according to Schulze).

Literature: Nägeli, Beitr. z. wiss. Bot., Heft 1, 1858, pp. 26 and 118.—Regnault, Cyclosp., Ann. sc. nat., sér. 4, t. xiv, 1860, pp. 139–44 and pl. 9.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 75 and 371.—De Bary, Vergl. Anat., 1877.—Krüger, Anom. Holzbild., Diss., Leipzig, 1884, p. 21.—Blenk, Durchs. P., Flora 1884, p. 375 et seq. and sep. copy, pp. 87–9.—Douliot, Faisc. méd. du *Phytolacca dioica*, Bull. Soc. bot. de France 1885, pp. 391–2.—Morot, Péricycle, Ann. sc. nat., sér. 6, t. xx, 1885, pp. 275–7.—Hérail, Tige des Dicotyl., Ann. sc. nat., sér. 7, t. ii, 1885, pp. 243–5.—Solereder, Holzstr., 1885, pp. 217–19.—Radlkofer, Durchs. P., Sitz.-Ber. Münch. Akad. 1886, pp. 326–7.—[Avetta, Anomalie di struttura nelle radici etc., Ann. dell' Ist. bot. di Roma 1887.]—Petit, Pétiole, Mém. Soc. sc. nat. et phys. de Bordeaux, sér. 3, t. iii, 1887, p. 241.—Eiselen, Rhaph., Diss., Halle a. S., 1888, p. 16.—Heimerl, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 b, 1889, p. 2.—Ross, Periderma, Malpighia, vol. iv, 1890–1, pp. 98–100.—Zimmermann, Pflanzenzelle, 2. Heft. 1891, p. 137.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 71–4.—H. Schenck, Anat. d. Lianen, 1893, pp. 53–5 and 252, Tab. ii.—Herbst, Markstr., Bot. Centralbl. 1894, i, p. 295 et seq.—[Kruch, Ricerche anat. ed istolog. sulla *Phytolacca dioica*, Ann. del R. Ist. bot. di Roma 1894, pp. 124–54, 3 Tab.]—C. Schulze, Anat. Bau d. Bl. u. d. Axe in der Fam. d. Ph. etc., Diss., Erlangen, 56 pp. and 1 Tab.—Kruch, [Cristalloidi della *Phytolacca abyssinica*, Atti della reale Accad. dei Lincei, vol. v, 1896, pp. 364–6] and Sferoidi e cristalloidi di alcune Fitolacche, Annuar. R. Ist. bot. di Roma, vol. vii, 1897, 11 pp. and Tab.

BATIDEAE.

This small Order, the systematic position of which is still uncertain, includes only the monotypic genus *Batis* with *B. maritima*, L.

The axis of this plant is normal in structure. In transverse section the mass of **wood** exhibits broad medullary rays, and rounded vessels with thick walls and of no great diameter (reaching ·03 mm.). The vessels have simple perforations. In contact with parenchyma of the medullary rays, the vessel-wall bears bordered pits. The wood-prosenchyma has thick walls, bearing small, but distinctly bordered pits. The wood-parenchyma is confined to the neighbourhood of the vessels. Regarding the structure of the **cortex** it may be mentioned that isolated, massive groups of primary bast-fibres are developed in the pericycle. In the secondary bast also scattered sclerenchymatous fibres with yellow walls are found. The formation of cork takes place in the pericycle on the inner side of the bundles of primary bast-fibres. In addition to the cork a large mass of phelloderm with abundant intercellular spaces is formed by the phellogen. **Oxalate of lime** is present

in the pith, primary cortex and bast, in the form of solitary crystals, which in some cases have a corroded appearance.

An important feature in the structure of the **leaf** lies in the fact that the stoma is enclosed by two semilunar subsidiary cells arranged parallel to the pore. The majority of the stomata are orientated so that their pores are transverse with regard to the longitudinal axis of the narrow leaf. Trichomes are not present. Oxalate of lime appears in the form of clustered crystals, crystal-conglomerates, and also solitary crystals.

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POLYGONACEAE.

1. Review of the Anatomical Features. The following features may be pointed out as characteristic of the Order: the absence of a special type of stoma, *the simple perforations of the vessels,* and *the simple pits borne by the wood-prosenchyma.* The pericycle shows different types of differentiation; the formation of cork is superficial or internal. Oxalate of lime forms clustered, or ordinary solitary crystals. The following types of internal secretory organs are found: cells with resinous contents (species of *Polygonum*); branched secretory cells with brown contents (cortex of the root in species of *Calligonum*); and elongated tannin-sacs (stem in species of *Polygonum* and *Fagopyrum*). The hairy covering consists chiefly of simple unicellular trichomes and glandular hairs, in which the head is small, or peltate and of larger size, being either unicellular or divided by vertical walls. Anomalous structure of the axis occurs in some cases, the following types being represented: development of secondary vascular bundles in the pericycle (*Antigonon*); occurrence of medullary vascular bundles (*Rumex, Rheum*), with wood and bast inversely orientated, or with concentric structure (the phloem being central); presence of intra-xylary phloem (*Emex*); development of bundles of soft bast in the interfascicular tissue of the phloem (*Polygonum, Fagopyrum*); or occurrence of cortical vascular bundles (*Calligonum*). The following special anatomical features can be employed in detailed diagnosis: mucilaginous epidermal cells in the leaf; subepidermal strands of sclerenchymatous fibres and aqueous tissue in the same position in the leaf and stem; hypoderm in the leaf; strands of collenchyma; the development of a characteristic sheath in the stem, and so on.

2. Structure of the Leaf. Since only scanty information has hitherto been obtained regarding the structure of the leaf in the Polygonaceae, it was necessary for me to make a rough survey by investigating a few representatives of the five tribes (*Eriogonum angulosum*, Benth., *Nemacaulis Nuttallii*. Benth., *Polygonum Bistorta*, L., *Rumex scutatus*, L., *Coccoloba ovata*, Benth., *C. longependula*, Mart., *Triplaris Pachau*, Mart.). On the basis of these and other investigations the following facts may be pointed out. In *Coccoloba ovata*, *Polygonum Bistorta*, the land-form of *P. amphibium*, L., in *P. equisetiforme*, Sibth. et Sm. and *P. aviculare*, the **epidermis** of the leaf contains cells in which the inner membranes are mucilaginous. According to Johow hypoderm occurs in some species of *Coccoloba*, such as *C. uvifera*. The **stomata** are always surrounded by several epidermal cells, which are not differentiated by their shape except in *Coccoloba* and *Triplaris*. They either occur on both sides of the leaf (*Eriogonum angulosum*, *Nemacaulis Nuttallii*, *Rumex scutatus*), there being very few on the upper

surface in some of these cases (*Polygonum Bistorta, Coccoloba ovata*), or they are confined to the lower side (*Triplaris Pachau*); in the floating leaves of the water-form of *Polygonum amphibium* they are of course only found on the upper side. The leaf-structure may be centric or bifacial. The leaves of *Polygonum equisetiforme*, a desert-plant, exhibit a sheath of palisade-tissue beneath the epidermis, and colourless aqueous tissue in the interior (Volkens). According to Dammer the vascular bundles of the **veins** (especially those of the median vein) are accompanied in *Coccoloba* by a varying amount of sclerenchyma; in species of *Polygonum* and *Rheum* the sclerenchyma is replaced by collenchyma. The occurrence of subepidermal strands of sclerenchymatous fibres in the leaf of *Polygonum equisetiforme* deserves special notice; they are separated from the assimilatory tissue by a layer of aqueous cells, which evidently serves to connect the palisade parenchyma (beneath these strands) with the water-storing epidermis. It may be added that similar sclerenchymatous strands are also found in the stem of *Polygonum aviculare*, L. (Grevillius) and *Calligonum comosum*, L'Hérit. (Volkens).

The **hairy covering** consists of clothing and glandular hairs. The clothing hairs are generally long simple unicellular trichomes (*Eriogonum, Nemacaulis*). In *Polygonum amphibium* there are also conical shaggy hairs on the leaves of the land-form; the cells of these hairs exhibit a multiseriate arrangement, and their tips project as papillae. In the glandular hairs the head is always unicellular, or divided by one or more vertical walls. In *Eriogonum angulosum* the glandular hairs are composed of a cylindrical or conical basal cell, a neck-cell, and a unicellular or bicellular head; in *Polygonum Bistorta* and *Rumex scutatus* there are sessile glands, the heads of which consist of from two to four cells, though sometimes unicellular in *Rumex scutatus*. Larger peltate glands are present in *Coccoloba* and *Triplaris*. They consist of a short stalk, composed of two cells lying side by side, and a shield with an entire margin; in *Coccoloba ovata* and *C. longependula* the shield is mainly divided by radial vertical walls, only a certain number of which reach the centre, whilst in *Triplaris Pachau* the shield is subdivided by division-walls, running in various directions, into a number of cells, which are four-sided or polygonal in surface-view. External glands, similar to those of *Polygonum* and *Rumex* described above, give rise to a mucilaginous gummy excretion on the buds in *Polygonum, Rheum* and *Rumex*; but here the glandular structure of the wall of the trichome is continued from the point of insertion of the latter into the smooth epidermis; there are also multiseriate, elongated glandular shaggy hairs of more complicated structure, and having the form of a lamella or band.

The **nectaries** found on the leaf-cushions of *Polygonum cuspidatum*, Willd., and of certain species of *Muehlenbeckia*, form depressions, in which shortly stalked peltate hairs are densely crowded together (Delpino and Morini); in these hairs the shield consists of prismatic cells, which are sometimes transversely divided.

The internal **secretory receptacles** include, in the first place, cells (or cavities ?), filled with yellowish contents, which are soluble in alcohol. Such secretory cells were found by Bokorny beneath the epidermis of the leaf in *Polygonum acre*, H. B. K., and occur also in *P. punctatum*, Ell.; they give rise to transparent dots in the leaf. Other forms are the branched secretory cells observed by Rindowsky in the cortex of the root in species of *Calligonum*, and the long tannin-sacs with brown, gelatinous contents, found by E. Schmidt in the stem of certain species[1] of *Polygonum*; the former have thin walls and are filled

[1] Viz. *P. amphibium*, *P. Hydropiper*, *P. lapathifolium*, *P. orientale*, *P. Persicaria*, *P. tinctorium*, *P. virginianum*; *Fagopyrum cymosum*, Meissn., *F. emarginatum*, Mch., *F. esculentum*, Mch., *F. tataricum*, Gaertn.

with a brown, tanniniferous gum-resin. The tannin-sacs resemble the well-known sacs of *Sambucus nigra*. They arise by the elongation of single cells, and attain a length of 12 cm. or more, so that they traverse entire internodes; in transverse section there is little to distinguish them from the neighbouring cells. They occur in the pith and bast, and sometimes also in the primary cortex and are not found in the subterranean shoots, or only in small numbers; they are not present in the roots. The brown contents, seen in the tannin-sacs in older stages, sometimes also appear in ordinary parenchymatous cells, which contain abundant tannin from the first. Here we may also mention the bright yellow or red contents in the cells of the medullary rays of the rhizome of rhubarb; they include the active chrysophanic acid.

Oxalate of lime is for the most part developed in the form of clustered crystals, but ordinary solitary crystals have also been observed [1].

The structure of the **petiole**, which has been investigated by C. de Candolle, Plitt and Petit, is uniform only in so far as the vascular bundles have an isolated course. In *Muehlenbeckia complexa* and *M. varians* the characteristic region exhibits two vascular bundles with their xylem-groups pointing towards one another. In *Rumex Acetosella* this part of the petiole contains an arc of isolated bundles, which is continued into the petiolar wings. In species of *Polygonum*, owing to the presence of one or more larger vascular bundles in a median position, the arc is converted into a closed ring; this is also the case in *Antigonon leptopus*. In the petioles of certain species of *Rumex* and *Rheum* there are numerous medullary vascular strands within a more or less distinct ring of isolated bundles; where the former become very numerous (*Rheum*), the vascular bundles of the petiole appear quite irregularly scattered in a transverse section.

The structure of the ochreate **stipules** has been examined by Grevillius and O. Schultz in species of *Rumex*, *Rheum*, *Polygonum* and *Fagopyrum*. The ochreae exhibit mechanical strengthening in a certain number of the species only; it may take the form of a thickened epidermis, the development of collenchyma on the inner (*P. aviculare* and *P. Raji*) or outer side (*P. divaricatum*) of the ochreae collenchymatous differentiation of the whole of the ground-tissue (*P. Hydropiper*, *Rheum*), the occurrence of rings or crescents of sclerenchyma accompanying the fibro-vascular system, or the differentiation of subepidermal strands of sclerenchymatous fibres (*P. amplexicaule*, *P. Bistorta*, &c.). A number of these anatomical features may occur side by side in the same species. Palisade-tissue has not been observed in the ochreae. Stomata occur, but are rare.

3. Structure of the Axis. The following statements regarding the structure of the **wood** are based on the investigation of woody species of the genera *Eriogonum*, *Chorizanthe*, *Calligonum*, *Muehlenbeckia*, *Coccoloba*, *Triplaris* and *Ruprechtia*. The arrangement of the vessels and the size of their lumina vary (maximum diameter = ·024–·07 mm.). The perforations are simple; the wall of the vessel bears bordered pits, where it is in contact with parenchyma of the medullary rays. Spiral thickening of the vessel-wall occurs in *Eriogonum fasciculatum*, Benth., *Chorizanthe paniculata*, Benth. and *Triplaris Pachau*, Mart. The medullary rays are generally from one to three cells in breadth [2], and according to Houlbert they are specially numerous; in *Chorizanthe paniculata* distinct medullary ray-tissue is not present. The wood-prosenchyma may be described as having simple pits; it is septate by means of thin transverse walls in species of *Muehlenbeckia*, *Coccoloba*, *Triplaris* and *Ruprechtia*. Chambered parenchyma containing crystals is found in *Coccoloba*.

The structure of the **cortex** has hitherto been little investigated. In

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[1] Walliczek's statement (Pringsheim Jahrb., Bd. xxv, 1893, p. 213) that raphides occur in the tissue of the petiole of *Rheum* is incorrect. The petiole only contains large clustered crystals.

[2] The herbaceous species are divergent in this respect (see Herbst. loc. cit.).

many cases, and especially in the herbaceous species, the primary cortex contains strongly developed, subepidermal strands of collenchyma, which project in the form of ribs. The collenchyma is occasionally replaced by subepidermal strands of sclerenchymatous fibres, which have been mentioned above in the section dealing with the structure of the leaf; in other cases (*Antigonon leptopus*, Hook. et Arn., certain species of *Rumex*, such as *R. Acetosa*, &c.) small vascular strands lie in the corners of the stem, and together with the larger bundles corresponding to the furrows constitute the normal vascular ring. An endodermis is sometimes developed in the herbaceous species. The pericycle frequently exhibits sclerenchymatous differentiation, either in the form of a continuous ring (*Antigonon leptopus*, *Polygonum* pro parte), or of isolated bundles of hard bast (*Polygonum*, pro parte). The development of cork takes place subepidermally (*Polygonum*), or in the pericycle (*Atraphaxis spinosa*, L., according to Avetta).

Anomalous structure of the axis is found in some members of the Order. Under this heading we may first mention the somewhat irregular formation of the xylem-mass brought about during growth in thickness in *Atraphaxis spinosa*, L. (xylem-mass irregularly lobed in the stem and root), according to Avetta, and in *Coccoloba striata*, Benth. and *C. ochreolata*, Wedd. (flattened or angular stems), according to H. Schenck. A true anomaly is described by Avetta in the stem and root of *Antigonon leptopus*, Hook. et Arn. In transverse section the five-angled stem of this species shows a 5-rayed pith: the latter is surrounded by a vascular ring composed of five larger and five smaller bundles alternating with one another, the smaller strands lying in the corners; outside the bundles there is a pericyclic ring of sclerenchyma. In the parenchymatous portion of the pericycle a secondary meristem produces five secondary vascular bundles, which round off the outline of the stem. Another anomaly, first discovered by Sanio in *Rumex crispus*, consists in the presence of medullary vascular bundles in certain species of *Rumex* and *Rheum* [1]. These bundles are generally collateral, and show inverse orientation of wood and bast, but in a few species (*Rumex cordifolius*, Horn., *R. domesticus*, Hartm., and *R. orientalis*, Bernh., according to Russow, Bergendal and Möbius) they are concentric with central phloem.

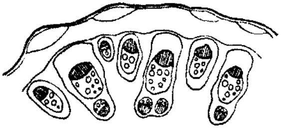

FIG. 161. Portion of a transverse section of the stem of *Rumex crispus*, L.—After Hérail.

The structure in question has been examined most carefully in *Rumex crispus* (Fig. 161) by Hérail. The appearance of a transverse section through the mature stem of this plant is very striking. A common sclerenchymatous sheath surrounds each outer (normal) vascular bundle, together with the inversely orientated strand situated on its inner side. At first the peripheral bundles alone are present, each of them being surrounded by a sclerenchymatous sheath at an early stage; subsequently groups of soft bast arise at the margin of the pith, and these soon become enveloped by sclerenchyma; at a still later stage cambium appears at the outer limit of each group of soft bast, and gives rise to the xylem of the medullary vascular bundle externally, whilst it adds to the soft bast internally; finally a small island of sclerenchymatous fibres makes its appearance in the middle of the phloem. The stem of *Rumex cordifolius* has a still more complicated structure (Möbius). In this species, in addition to other peculiarities (such as concentric vascular strands, &c.), we find not only double vascular bundles, as in *R. crispus*, but even triple bundles,

[1] These are: *Rumex confertus*, Willd., *R. cordifolius*, Horn., *R. crispus*, L., *R. domesticus*, Hartm., *R. Hydrolapathum*, Huds., *R. longifolius*, *R. maximus*, *R. orientalis*, *R. Patientia*, *R. undulatus* and *Rheum Ribes* (Petersen, Hérail, Möbius).

›wing to the appearance of a third bundle with inwardly directed xylem on the nner side of the inversely orientated medullary vascular strand.

Having described the occurrence of medullary vascular bundles, we may ıext consider the presence of intraxylary soft bast in *Emex*; the peculiar treaky structure of Radix Rhei; the appearance of bundles of soft bast, .rising independently in the interfascicular tissue of the phloem, in numerous pecies of *Polygonum* and *Fagopyrum*; and the occurrence of cortical vascular ›undles in *Calligonum comosum*, L'Hérit.

Intraxylary soft bast has been demonstrated by Petersen in *Emex spinosa* and *:entropodium*; it only occurs opposite a certain number of the vascular bundles; ccording to Möbius, it appears also to be present in species of *Rheum* and *Polygonum*. 'he streaky structure of Radix Rhei has been examined in detail by Schmitz and)utailly. In the tuberous branches of the rhizome of the officinal rhubarb-plant *Rheum officinale*, Baill.) the collateral leaf-trace strands form a normal vascular ring nclosing a pith, which is continually undergoing increase in size. In a young branch f the rhizome the pith is traversed by a complete network of anastomosing strands

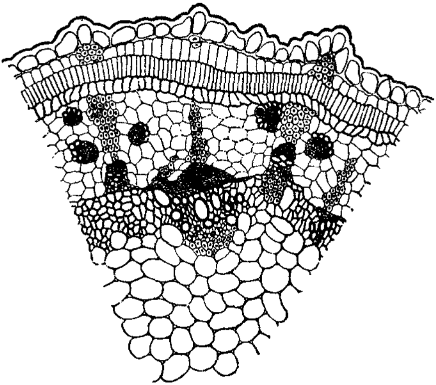

FIG. 162. Transverse section through the axis of *Calligonum comosum*, L'Hérit.—Original.

f soft bast, which are arranged in transverse zones, following closely upon ne another and corresponding to the nodes; these strands unite the leaf- 'aces, and are also connected with one another by bundles, which traverse the ıternodes either in a vertical or oblique direction, and mostly run in the neighbour- ood of the xylem-ring. Around each of these strands of soft bast a cambial ring, eveloped at an early stage, produces rays of soft bast on its inner, and rays of wood ith abundant parenchyma on its outer side, whilst between the rays of wood and ast it gives rise to medullary ray-tissue, which becomes filled with red colouring- ıatter. Thus the radiate rings, or streaks, are medullary vascular bundles with eripheral xylem. Besides occurring in *Rheum officinale*, they are found in *R. Emodi*, . *Rhaponticum* and *R. palmatum*, but they are not present in *R. rugosum* and other ›ecies. The groups of soft bast found in species of *Polygonum* and *Fagopyrum* have een examined in detail by E. Schmidt; they arise between the phloem-groups of ıe stem, and become connected with the vascular bundles at the nodes; with regard › their relation to growth in thickness see Schmidt, loc. cit. The cortical vascular undles of *Calligonum comosum*, L'Hérit. (a desert-plant with advanced reduction f the foliar organs), and of other species, are associated with a series of other note-

rorthy structural features, such as the differentiation of palisade-tissue in the rimary cortex, the development of a characteristic sheath of collecting cells below he palisade layer (similar to that in the Salsoleae), the development of aqueous tissue a the cortex, and so on (for details see Fig. 162).

From the xerophilous structure of *Calligonum* we may pass to the anatomy of he **phyllocladea** of *Polygonum platycladum*, F. v. Müll. According to Pick, the cortex ontains two or three layers of palisade-tissue, limited internally by a zone of sclerenchymatous fibres. The sclerenchymatous tissue bears prominences reaching as far as he epidermis, and thus has the form of a wreath, in which the elongated arcs are oncave towards the exterior and enclose the assimilatory tissue, whilst the vascular oundles lie in the small internal concavities of the wreath.

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PODOSTEMACEAE.

In external appearance the Podostemaceae remind one of Lichens, thalloid Liverworts, Jungermanniaceae and Algae rather than of Phanerogams. In accordance with the object of this book, their anatomical features will be quite shortly considered. In some cases, we find resemblances to Algae in the internal structure as well as in the external characters. The shoots are composed of fairly uniform tissue, which is very frequently collenchymatous, especially in the neighbourhood of the vascular bundles. Stomata are entirely absent. The epidermal cells sometimes contain chlorophyll. The vascular bundles are never strongly developed; the xylem contains a few annular and spiral tracheids, but sometimes even these are absent (root of *Mniopsis Weddelliana*, Tul.), or they become abortive at an early stage and replaced by an intercellular space (stem of *Tristicha hypnoides*, Spreng.). In the phloem the sieve-tubes are not always distinct, but in many species

they are readily seen and together with their companion cells form characteristic groups of cells. An endodermis is not developed. In transverse section the stem shows more or less distinct dorsiventrality, depending on the position of the vascular bundles and the differentiation of the ground-tissue. As a rule there are only a few isolated vascular bundles in the stem; they are placed side by side, so that there is no vascular ring. In *Hydrostachys imbricata*, Juss., on the other hand, a ring of isolated vascular bundles occurs in the axis of the inflorescence, while additional medullary and cortical strands are also present. In the structure of the root the dorsiventrality is still more distinctly marked than in the axis. The vascular system is nearer to the ventral than to the dorsal side of the root, and consists of two vascular bundles, which are placed side by side, and fused together; the two xylem-groups are situated ventrally, but may be absent.

Trichomes have only been met with on the leaf in a few members of the Order; they occur in the form of short, tubular protrusions of the epidermal cells, and have a secretory function. Clustered crystals of oxalate of lime have also only been observed in a few cases (*Hydrostachys* and *Lawia*). Intercellular spaces, resembling resin-canals (without any secretion visible in alcohol material), occur in the root of *Weddellina squamulosa*, Tul. On the other hand peculiar siliceous concretions are very widely distributed; they were already observed by Tulasne, but were only correctly interpreted for the first time (almost simultaneously) by Cario and Warming.

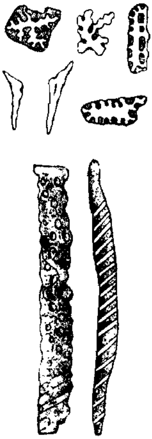

FIG. 163. Silica-bodies of *Tristicha hypnoides*, Spreng.—After Cario.

The silica-bodies are found in many species, and often occur in great abundance; they are principally to be met with in the peripheral parts of the root, stem and leaf, and especially in the epidermis (even in the trichomes). When the silica-bodies are abundant, the organs above referred to possess, as it were, a coat of armour, which is regarded as a protective arrangement against mechanical injuries, the attacks of animals, and desiccation. Thus, according to Warming, the silica-bodies are so abundant in *Podostemon Galvonis* that the plant has the same appearance in the dry state as when fresh; on the other hand, plants of *P. subulatus*, a species which is almost devoid of silica, become greatly shrunk in drying. In those plants, however, which have a complete subepidermal siliceous armour, the latter does not form an absolutely closed sheath, but exhibits various 'passage-ways.' The appearance of the silica-bodies varies in the same species. In most cases they fill the entire lumen of the cell. Sometimes they are absolutely homogeneous and vitreous, but frequently it is only the onter part of the silica-body that has this homogeneous structure, the interior appearing dull owing to the presence of a quantity of small gas-vacuoles. The shape of the silica-bodies is also very varied, even in the same species, as is shown sufficiently clearly by some of Cario's figures reproduced here (Fig. 163). The surface of the silica-bodies is either smooth, or shows spiral or annular ridges, or is corroded in a very peculiar manner so as to exhibit a varying number of depressions or excavations. Warming and Kohl regard the silica-bodies in question as structures formed in the cell-cavity, and hence homologous with the well-known stegmata of Palms and other Monocotyledons; the same observers attribute their varied shape to the influence of other contents, component parts of the cell, such as the nucleus, chlorophyll-bodies and starch-grains. According to Strasburger's investigations on *Mniopsis Weddelliana*, we are not in this case dealing with a deposition of silica in the living protoplasm, but rather with a progressive transformation of the superficial portion of the protoplasm from without inwards.

Literature: Tulasne, P. Monogr., Arch. Mus. d'hist. nat., t. vi, 1852, pp. 4 and 10 et seq.—Cario, *Tristicha hypnoides*, Bot. Zeit. 1881, p. 25 et seq. and Tab. i.—Warming, Kiselsyredannelser hos P., Vidensk. Meddelels. naturh. For. i Kjöbnhavn, 1881, pp. 89–92, with a French résumé.—Strasburger, Zellhäute, Jena, 1882, pp. 234–5.—Warming, Familien P., Vidensk. Selsk. Skr., 4 Abh., Danish with a French résumé I: 1881, 34 pp. and 6 Tab.; II: 1882, 88 pp. and 9 Tab.; III: 1888, 72 pp. and 12 Tab.; IV: 1891, 47 pp.; V: 1899—Kohl, Kalks. u. Kiesels., 1889, pp. 249–67 and Tab. v.—Warming, in Natürl. Pflanzenfam., iii. Teil, Abt. 2 a, 1890, pp. 3 and 8–9 and *Hydrostachys*, Bull. Acad. roy. Danoise des sc. et lettres 1891, sep. copy, 7 pp.—Wächter, *Weddellina squamulosa*, Beitr. z. K. einig. Wasserpfl., Diss., Rostock, 1897, pp. 18–33, sep. copy from Flora 1897.

NEPENTHACEAE.

This Order comprises the single genus *Nepenthes*, widely known on account of its peculiar ascidiform leaves or pitchers, which are adapted for the capture of animals, and actually digest animal substances. The genus has been repeatedly investigated owing to its interesting foliar organs, and its anatomy is consequently well known.

The **leaf** of *Nepenthes* consists of three parts; there is a lamina, which is produced into a cylindrical portion usually serving as a tendril, and terminates in a pitcher, provided with a lid.

The lamina has the type of structure usual for a leaf, as my own observations showed. The **mesophyll** is in some cases (*N. gracilis*, Korth. and *N. Boschiana*, Korth.) distinctly bifacial, being differentiated into palisade and spongy tissue, of which the former consists of a few layers of short, broad cells; in other species, such as *N. ampullaria*, Jack and *N. albomarginata*, Lobb., the palisade-tissue is scarcely distinguishable. The lateral margins of the **epidermal cells** are straight in most of the species investigated; in *N. ampullaria* only they are curved on the lower side of the lamina. In the epidermis of the lamina **stomata** occur on the lower side only; they are also present on both surfaces of the lid, and on the outer side of the pitcher itself. The stomata are surrounded by several epidermal cells; those of the lamina are arranged approximately parallel to one another, and with their pores parallel to the midrib. The integumental tissue of the lamina is supplemented by a water-storing **hypoderm**. The latter is developed more especially beneath the upper epidermis, where it usually forms a continuous layer of cells with large lumina, considerably exceeding the epidermal cells in diameter (*N. gracilis*, *N. ampullaria* and *N. albomarginata*); in *N. gracilis* the cells are elongated transversely to the median vein in surface-view, while in other cases they are approximately isodiametric. In *N. Boschiana* there is a layer of small cells lying immediately beneath the epidermis, and followed by the large-celled hypoderm. On the lower side of the lamina the lowest layer or layers of cells of the mesophyll also assume the character of a hypoderm. The vascular bundles of the **veins** are provided with mechanical tissue. The course of the veins is peculiar. There are, firstly, two or more lateral veins, running parallel to the principal vein, while additional systems of delicate, much branched, and anastomosing veins arise at short intervals from the midrib and run near the upper side of the leaf. The mesophyll of the lamina, and also the ground-tissue of the lid, pitcher and axis, are specially distinguished by the presence of spiral cells (Fig. 164, *A–B*), serving for the storage of water. These cells are mostly tubular, closed on all sides, and devoid of contents; they are ·09–3·33 mm. in length and ·045–·13 mm. in breadth; their walls are stiffened by a spiral band, composed of three or more partial bands. Both the wall and the spiral band consist of cellulose.

Usually the inner wall of the **pitcher** may be divided into two sharply separated zones, the slippery and the glandular zone, which one can distinguish

on examining the internal surface with the naked eye; sometimes they are even recognizable from the outside. The slippery zone occupies the upper, the glandular zone the lower portion of the pitcher. The relative areas occupied by these two zones on the inner wall of the pitcher vary. In some cases the line of demarcation between them is only a few millimetres beneath the mouth of the pitcher (*N. villosa*, Hook. f., *N. Edwardsiana*, Low, according to Wunschmann), but more commonly it lies in the middle of the pitcher. The slippery zone is rarely completely absent (*N. bicalcarata*, Hook., *N. madagascariensis*, Poir., *N. Rajah*, Hook. f., and in some cases in *N. ampullaria*, Jack and *N. Rafflesiana*, Jack, according to Wunschmann). This zone is specially distinguished by the absence of glands. Its surface is not wetted by water, as it is covered with a granular layer of wax, which sometimes has a blueish or reddish colour. In the epidermis of this layer, besides cells of the ordinary type there are others which are semilunar and resemble guard-cells; they project somewhat like papillae, and have their concave sides directed towards the base of the pitcher (Fig. 164, *C*[1]). The glandular zone bears numerous **glands** of characteristic structure (digestive-glands). These (Fig. 164, *D–F*) are wart-like bodies and may be seen even with a lens to lie in pockets, which are open towards the base of the pitcher; the pockets are produced by elongation of the row of epidermal cells bordering on the upper margin of the gland so as to form a roof with a sharp edge, covering about one half, or sometimes the whole of the gland, or in other cases only a small portion of it. The glands themselves are placentiform masses, consisting of either two or three horizontal layers of cells, of which the uppermost is differentiated like palisade-tissue, and appears as a finely polygonal network in surface-view; the gland is separated from the internal tissue of the wall of the pitcher by one or more layers of cells, which when multiseriate are arranged like cork-cells, and have some of their walls suberized (Fig. 164, *F*). Another important fact is that tracheal strands, springing from branches of the veins, invariably terminate beneath the glands.

Glands of a similar structure to those described above, though sometimes very different in appearance, are also found on other parts of the vegetative organs, viz. on the stem, the petiole, the midrib of the leaf, the lower and in rare cases also the upper side of the lamina, as well as on the tendril, the outer side of the pitcher, the inner and outer surface of the lid, and the margin of the collar of the pitcher. These glands, however, excrete honey, and have the function of attracting insects. Their structure has been examined especially by Macfarlane, and in all cases agrees with that of the digestive-glands in the following respects: the surface of the glands is formed by two or three layers of secretory cells, the uppermost of which is composed of palisade-like cells; the secretory portion is limited internally by one or more layers of cells, some of which are suberized; tracheal terminations are invariably found beneath the gland. The glands, which occur on the inner side of the lid in variable numbers (numerous in *N. Boschiana*, few in *N. albomarginata*), agree closely with the digestive glands in their flattened placentiform shape, and in being composed of three horizontal layers of cells; they lie in small pits, which are overarched on all sides or on one side only (the upper) by a projecting flap of tissue formed by the adjacent epidermal cells. The marginal glands of the collar are likewise convex multicellular structures, but they have an elongated form, and are sunk in pits of a corresponding shape and often of considerable depth; in these glands the layers of glandular cells cover the

[1] These cells have nothing to do with the deposition of wax. Macfarlane found transitions between them and normal stomata, and supposes that they take part in the excretion of water in the interior of the pitcher.

entire convex surface, apart from the insertion of the gland. The glands, described by Macfarlane as occurring on the other portions of the ascidium enumerated above and on the stem in various species, are essentially different. In

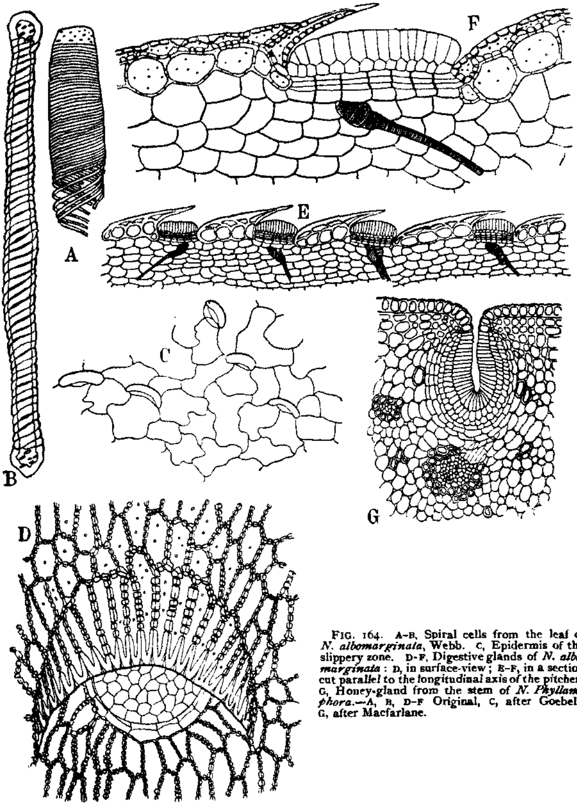

FIG. 164. A–B, Spiral cells from the leaf of *N. albomarginata*, Webb. C, Epidermis of the slippery zone. D–F, Digestive glands of *N. albomarginata*: D, in surface-view; E–F, in a section cut parallel to the longitudinal axis of the pitcher. G, Honey-gland from the stem of *N. Phyllamphora*.—A, B, D–F Original, C, after Goebel, G, after Macfarlane.

them the layers of glandular cells form the wall of a depression in the surface of the organ, the shape of the depression varying in different cases. The depressions are either shallow and widely open (leaf-glands of *N. hybrida*), or have the form of deep and narrow canals (stem-glands of *N. Phyllamphora*, Fig. 164, G), or of larger cavities, provided with numerous recesses and opening

to the exterior by means of a narrow ostiole (petiolar glands of *N. bicalcarata*; glands occurring on the inner side of the lid of the pitcher in *N. laevis*[1], *N. Lowii* and *N. Pervillei*).

In the **axis** (*N. Phyllamphora*, Willd., *N. Boschiana*, Korth.) the normal vascular ring is supplemented by numerous cortical vascular bundles, which form a special annular zone in the primary cortex. According to Zacharias

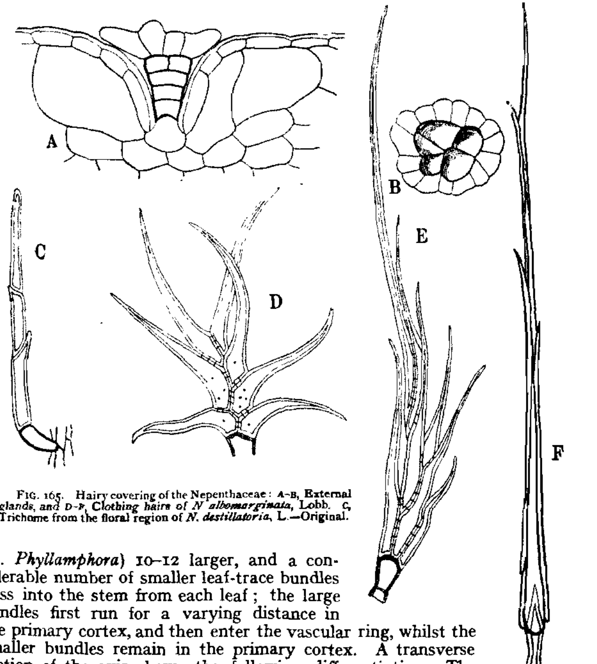

FIG. 165. Hairy covering of the Nepenthaceae: A–B, External glands, and D–F, Clothing hairs of *N. albomarginata*, Lobb. C, Trichome from the floral region of *N. destillatoria*, L.—Original.

(*N. Phyllamphora*) 10–12 larger, and a considerable number of smaller leaf-trace bundles pass into the stem from each leaf; the large bundles first run for a varying distance in the primary cortex, and then enter the vascular ring, whilst the smaller bundles remain in the primary cortex. A transverse section of the axis shows the following differentiation. The pith, which contains spiral cells, elongated in the vertical direction, is surrounded by a medullary sheath of elongated prosenchymatous or parenchymatous elements, provided with slit-like pits and subdivided by delicate transverse walls. Outside the medullary sheath lies the ring of vascular bundles. The pericycle contains hard bast accompanied by numerous spiral cells, which are elongated in the vertical direction; adjoining these elements is the endodermis. The primary **cortex**

[1] The glands described above are not present in *N. gracilis*, with which *N. laevis* is frequently confounded.

commences with a zone of large parenchymatous cells, amongst which short spiral elements occur; the parenchymatous cells themselves sometimes (*N. Boschiana*) possess spiral thickening, or spirally arranged slit-like pits. Outside the parenchymatous zone is a ring of mechanical tissue exhibiting the same structure as the medullary sheath and having the cortical vascular bundles embedded in it; external to this is a small-celled tissue containing chlorophyll and including spiral cells. The development of cork takes place immediately beneath the endodermis. In the structure of the **wood** we may mention that the vessels attain a diameter of ·07–·09 mm., and have simple perforations; the medullary rays are narrow and the wood-prosenchyma is provided with typical bordered pits.

Oxalate of lime occurs in the form of clustered crystals. In addition to these, sphaerocrystalline masses, the nature of which is not known, have been observed in alcohol-material (Zacharias). Internal secretory receptacles are *not present*.

The **hairy covering**, apart from the digestive and honey-glands described above, is constituted by peltate glandular hairs and by clothing hairs, as my own investigations proved. The former consist of (*a*) a basal cell; (*b*) a rather long stalk with fairly thick walls, and divided by horizontal septa, the uppermost tier being bicellular owing to the presence of a vertical wall; and (*c*) a deciduous peltate head, which sometimes (*N. gracilis*, according to Haberlandt) has a four-rayed form, and is divided into a number of cells (four or more) by variously orientated vertical walls (Fig. 165, *A–B*). The clothing hairs are of the following types: 1. simple uniseriate trichomes, which are occasionally (in the floral region of *N. destillatoria*, Fig. 165, *C*) characterized by oblique transverse walls and lateral protrusion of certain cells of the hair; 2. trichomes of more complicated structure appearing to the naked eye like tufted or stellate hairs (Fig. 165, *D–E*) or bristles (Fig. 165, *F*); some of these may be regarded as derived from uniseriate hairs of sympodial structure, whilst others are combinations of similar trichomes with stellate hairs; and 3. lastly, stellate hairs with a unicellular stalk and several ray-cells.

Literature: Wunschmann, *Nepenthes*, Diss., Berlin, 1872, 46 pp. (here and in DC. Prodr. xvii, p. 91 the older anatomical literature).—Zacharias, Stamm d. Gatt. *Nepenthes*, Diss., Strassburg, 1877, 32 pp. and 3 Tab.—Kny and Zimmermann, Spikularzellen von *Nepenthes*, Ber. deutsch. bot. Gesellsch. 1885, pp. 123–8.—Solereder, Holzstr., 1885, pp. 221–2.—Heckel and Chareyre, Ascidies etc., Compt. rend., t. ci a, 1885, p. 581.—Goebel, Biolog. Schild., ii. Teil, Lief. 1, 1891, pp. 107–10 and Tab. xxii.—Wunschmann, in Natürl. Pflanzenfam., iii. Teil, Abt. 2, 1891, pp. 256–7.—Macfarlane, Pitchered plants, Ann. of Bot., vol. vii, 1893, especially pp. 420–40 and pl. xix–xxi.—H. Schenck, Anat. d. Lianen, 1893, p. 72.—Haberlandt, Trop. Laubbl. ii, Sitz.-Ber. Wiener Akad., Bd. civ, Abt. 1, 1895, p. 97 and Tab. iv.

CYTINACEAE.

This Order, as is well known, comprises parasitic herbaceous plants, which are for the most part leafless, and in other respects also show considerable reduction of the vegetative organs.

This reduction is most pronounced in the tribe Rafflesieae, where the vegetative organs have the form of a thallus, embedded in the tissues of the host-plant; according to Solms-Laubach, this structure is mycelial and devoid of vascular tissue in the simplest cases (*Rafflesia, Brugmansia, Pilostyles Haussknechtii*, Boiss.), whilst vascular bundles occur in the more massive thallus of *Pilostyles aethiopica*, Welw. and *Cytinus Hypocystis*, L. Unlike the Rafflesieae the members of the second tribe, the Hydnoreae, consisting of the two genera *Hydnora* and *Prosopanche*, possess 'rhizoid-shoots.' The structure of these rhizoids has been examined in detail by Schimper in *Prosopanche Burmeisteri*,

De Bary, *Hydnora africana*, Thunb., and *Hydnora abyssinica*, A. Br.; in the first two species the rhizoids are angular in cross-section, in the last species they are cylindrical. In all three species the periphery of the transverse section shows a thick layer of cork-cells. These surround a parenchymatous cylinder containing the vascular bundles; the cells of the parenchyma are filled with brown, tanniniferous, gelatinous contents, which sometimes also include starch and tetragonal crystals of oxalate of lime. The tissue forming the innermost portion of the rhizoids consists of a strand of elongated cells (pith), which in *Prosopanche* are extremely long and fibrous, while in the remaining genera they are somewhat elongated and prismatic. The arrangement of the vascular bundles differs in the three species investigated. In *Hydnora africana* a transverse section shows the usual ring of normally orientated vascular bundles (xylem inwards, phloem outwards), the ring having five projections corresponding to the usually pentangular shape of the rhizoid; a few vascular bundles are also found scattered in the ground-tissue external to the ring. In *Prosopanche Burmeisteri*, in which the rhizoids are likewise 4–5 angled, the distribution of the vascular bundles in the parenchymatous ground-tissue is somewhat modified. In this plant the vascular ring is broken up into (*a*) a central zone of four or five normally orientated vascular bundles, which are placed singly opposite the concave lateral surfaces, and (*b*) four or five peripheral groups of bundles; each of these groups lies in one of the corners of the stem and is composed of two radial rows of bundles; the xylem-groups in the bundles of one row are directed towards those of the other. In *Hydnora abyssinica*, finally, a transverse section of the rhizoid shows several rings of normally orientated vascular bundles. Regarding the structure of the vascular bundles, I may mention that distinct sieve-tubes and simple perforations in the vessels have been observed in *Prosopanche*, and that the bundles sometimes show slight growth in thickness. We may also note the occurrence of peculiar secretory receptacles in the rhizoid-shoots of *Prosopanche Burmeisteri*; Schimper terms them receptacles of gelatinous substance, and De Bary found them also in the peduncle of the same plant. They form cylindrical strands of large, loosely connected cells with gelatinous contents, the strands sometimes attaining a diameter of 2 mm.; in many cases the more central cells sooner or later become disorganized, and replaced by an intercellular canal containing 'gelatine.' The 'gelatine-receptacles' are restricted to the radii connecting the angles of the stem (in transverse section) with the centre; on each of these radii there are either two or three receptacles, which decrease in size centrifugally.

Stomata appear not to be present in any member of the Order, not even on the floral organs. Glandular hairs are figured by Chatin (Taf. xcii, Fig. 3) on the bracts of *Cytinus Hypocystis*; a glandular head, composed of three or four cells separated by vertical walls, is seated on a conical multicellular pedestal.

Literature: Chatin, Anat. comp., Pl. parasit., pl. xc bis–xcii bis and cii–cvii (without text).—De Bary, *Prosopanche*, Abh. naturf. Gesellsch. Halle, Bd. x, 1868, pp. 241–69 and 2 Tab.—Solms-Laubach, *Pilostyles Haussknechtii*, Bot. Zeit. 1874, pp. 49 and 65 et seq. and Tab. i and Haust. d. Loranth. u. Thallus der Rafflesiac. etc., Abh. naturf. Gesellsch. Halle, Bd. xiii, 1874, pp. 259–67 and Tab. xxv–xxvi.—Schimper, *Prosopanche*, Abh. naturf. Gesellsch. Halle, Bd. xv, 1882, pp. 21–47 and Tab. ii–iii.—Solms-Laubach, in Natürl. Pflanzenfam., iii. Teil, Abt. 1, 1889, pp. 275 and 284.—Peirce, Haustoria, Ann. of Bot., vol. vii, 1893, p. 318 et seq. and pl. xiv–xv.

ARISTOLOCHIACEAE.

1. Review of the Anatomical Features. This Order is characterized by the following features: (*a*) the presence of secretory cells with oily contents (Fig. 166, *A–C*), probably occurring in all the species, and sometimes giving rise to transparent dots in the leaf, where they show a tendency to be restricted to the epidermal tissue; (*b*) the lack of a special type of stoma; and (*c*) the absence of glandular hairs. In the woody species other characters may be added, viz. the broad primary medullary rays, the simple perforations of the vessels, the bordered pitting of the wood-prosenchyma and the absence of secondary hard bast. The development of **cork**, as far as it is known, takes place superficially; in the woody species the pericycle contains a continuous, or interrupted, composite ring of sclerenchyma. In addition to the secretory cells, spherical cells, filled with brown, tanniniferous contents, are present in certain species of *Aristolochia* and *Holostylis*. Oxalate of lime is generally excreted in the form of small prismatic or clustered crystals, very rarely as ordinary large solitary crystals. Groups of cells with silicified walls (Fig. 166, *D–G*) are common in *Holostylis* and the species of *Aristolochia*, while cells with siliceous contents (Fig. 166, *H–J*) are present in all species of *Apama* and *Thottea*. The hairy covering consists of uniseriate trichomes of varied structure; in species of *Aristolochia*, *Holostylis*, *Thottea* and *Apama* these trichomes assume a special form, viz. bracket-hairs (Fig. 166, *K*), in which the terminal cell is bent like a hook; another special type is that of the trichomes of *Saruma*, where the terminal cell encloses fine crystal-sand composed of oxalate of lime. Anomalous structure of the axis has only been met with in *Aristolochia triangularis*, Cham. (Fig. 167, *B*) (splitting up of the original vascular ring, and secondary formation of bundles of wood and bast at the inner margin of the resulting segments). For the purposes of finer anatomical diagnosis the following characters have special systematic importance: the details of the distribution, or the absence (*Aristolochia*, section *Siphisia*) of secretory cells in the leaf; the occurrence of hypodermal tissue in the leaf (species of *Aristolochia* and *Thottea*); and the papillose differentiation of the upper (species of *Asarum*) or lower (species of *Aristolochia* and *Thottea*) epidermis.

2. Structure of the Leaf. This has been thoroughly investigated[1]. The leaf is generally bifacial, but in some cases the mesophyll consists of homogeneous muriform parenchyma. Centric leaf-structure with palisade-tissue developed on both sides is rare (*Aristolochia auricularia*, Boiss., &c.). The **stomata** have no special subsidiary cells, and in the great majority of species occur only on the lower surface of the leaf. In certain species of *Asarum* and *Aristolochia* and in *Holostylis* they are met with on both sides of the leaf, whilst in *Apama* and *Thottea* they have been observed on the lower surface only. It is a noteworthy fact that the cuticle is not striated in any of the Aristolochiaceae, but it frequently has a granular structure. Gelatinization of the **epidermis** of the leaf has not been observed. Development of hypoderm is rare. *Thottea grandiflora*, Rottb. is distinguished from other species of the same genus by possessing a hypoderm situated beneath the upper epidermis of the leaf and composed of a single layer of thick-walled cells with undulated lateral walls; hypoderm is also found on the upper side of the leaf in *Aristolochia oblongata*, Jacq., and less completely differentiated in *A. sericea*, Benth. Papillose development of the epidermis of the leaf has been demonstrated in species of *Asarum*, *Aristolochia* and *Thottea*. In the species of *Asarum* in which this feature

[1] See Solereder, in Engler, Bot. Jahrb. 1889, loc. cit.

is found (*A. Blumei*, Duch., *A. canadense*, L., *A. Thunbergii*, A. Br. and *A. variegatum*, A. Br. et Bouch.) the papillae occur on the cells of the upper epidermis; in the other cases they are developed on the lower epidermal cells (*Thottea dependens*, Klotzsch, *T. grandiflora*, Rottb., *T. tricornis*, Maingay; *Aristolochia albida*, Duch., *A. Clematitis*, L., *A. contorta*, Bge., *A. cymbifera*, Mart. et Zucc., *A. cynanchifolia*, Mart. et Zucc., *A. debilis*, Sieb. et Zucc., *A. hians*, Willd., *A. nervosa*, Duch., *A. ringens*, Vahl and *A. Uhdeana*, Duch.). In *Aristolochia ringens* and certain other species the formation of papillae is restricted to the veins, and occurs especially where several of the smaller veins meet; in *A. contorta* the papillae are sometimes very long, resembling hairs, and some of them may even become bicellular owing to the formation of transverse walls. The vascular system of the smaller **veins** is invariably embedded; in many species it is accompanied by varying amounts of sclerenchyma, whilst in other species the sclerenchyma is entirely wanting.

The **secretory cells** (Fig. 166), which in many species give rise to transparent dots in the leaf, require a more detailed description. They occur not only in the leaves, but also in all the other organs, such as stem, rhizome, root, flower, fruit and seed. The secretory cells in the lamina of the leaf have been especially examined. They are found in the lamina in nearly all the members of the Order, being absent only in a few very closely related species of *Aristolochia*, belonging to the section *Siphisia* (namely *A. Kaempferi*, Willd., *A. platanifolia*, Duch., *A. Serpentaria*, L., *A. Sipho*, L'Hérit. and *A. tomentosa*, Sims.). In these species, however, the secretory cells are met with in other organs of the plant, so that their general occurrence may be regarded as a specially valuable and constant character of the Order. The following statements may be made regarding the distribution of the secretory cells in the tissues of the lamina in the various genera of the Aristolochiaceae, to which I am able to add the new genus *Saruma*, Oliv. on the basis of a recent investigation. There is a general tendency in this Order to the development of secretory cells in the integumental tissue. In the genus *Asarum* they are invariably found in the epidermis, and in certain species they occur in the mesophyll as well; the monotypic genus *Saruma* possesses secretory cells in the lower epidermis and in the mesophyll; in *Thottea* they occur only in the mesophyll; in *Apama* in the mesophyll—in certain species in the epidermis also; in the genera *Holostylis* and *Aristolochia* exclusively in the integumental tissue: generally in the epidermis, rarely in the hypoderm on the upper side of the leaf (*A. oblongata*, Jacq.), or as basal cells to the uniseriate hairs (*A. sericea*, Benth., Fig. 166, *A*, *A. Griffithii*, Hook. f. et Th. and *A. saccata*, Wall., in all of which independent secretory cells are wanting). The secretory cells occurring in the epidermis of the leaf are either present on both sides or only on the lower side; they are never found in the upper epidermis only; their varied mode of occurrence may be employed systematically in the case of the species of *Asarum* and *Aristolochia*, and the same applies to the distribution (referred to above) of the secretory cells in both mesophyll and epidermis, or in only one of these two tissues. The shape of the secretory cells is mostly spherical or ellipsoidal; branched forms are of rare occurrence (*Aristolochia nervosa*, Duch.). The size of these elements varies, their diameter being between ·075 and ·012 mm. Their walls are usually suberized. The contents consist of drops of a yellowish or whitish, or occasionally reddish substance, and include ethereal oil. They are not of uniform chemical composition; in *A. Lindeniana* Duch. var. *plagiophylla*, Griseb. the contents of the secretory cells become coloured indigo-blue by Eau de Javelle, this being due to the conversion of some substance present in the secretion into indigo. The secretory cells in the epidermis require special description, since frequently only a small portion of each of these cells reaches the free surface of the leaf, while they often penetrate

deeply into the mesophyll (Fig. 166, *B*); consequently, if one examines a transverse section of the leaf in a superficial manner, they appear to belong to the

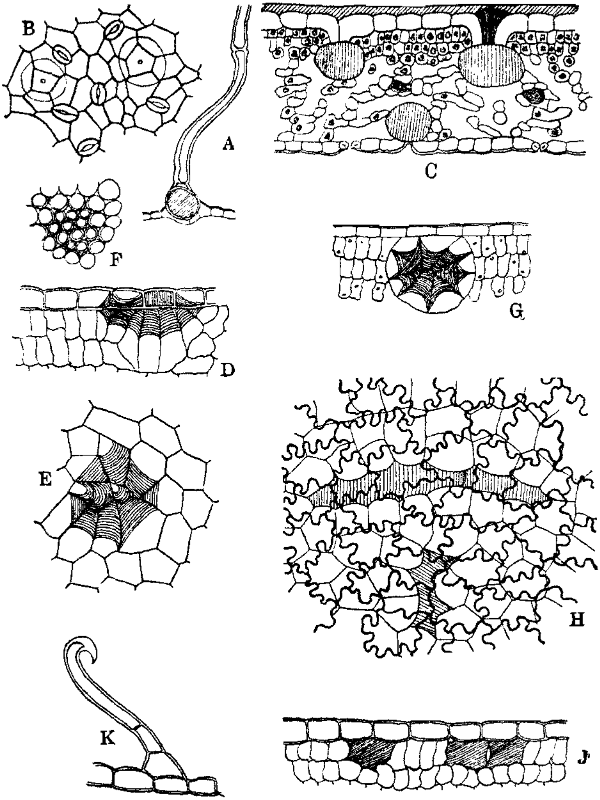

FIG. 166. A, Hair of *Aristolochia sericea*, Benth. with a basal secretory cell. B, Secretory cells in the lower epidermis of the leaf of *A. brachyura*, Duch. C, Transverse section of leaf of *A. trichostoma*, Griseb. D–F, Silicified group of cells from the leaf of *A. tomentosa*, Sims.: D, in section; E, silicified group of epidermal cells; F, group of subjacent palisade-cells in surface-view. G, Silicified group of cells in the mesophyll of *A. acutifolia*, Duch. H–J, Siliceous cells in the leaf of *Thottea dependens*, Klotzsch: H, in surface-view; J, in section. K, Bracket-hair of *Aristolochia tomentosa*, Sims.—Original.

mesophyll, though this is really not the case. The small portion of the epidermal secretory cell which appears at the surface, occasionally lies at the

bottom of a small pit-like depression in the surface of the leaf (especially in *A. trichostoma*, Griseb., Fig. 166, *C*, and *A. spathulata*, Duch.). Not uncommonly the external surface of the secretory cell exhibits a centrally placed dot, which has been shown to be due to a small, circular, thinner portion of the outer wall (Fig. 166, *B*). The secretory cells of the axis occur not only in the epidermis, but also in the pith, primary cortex and medullary rays. Spherical cells filled with brown, tanniniferous contents must not be confounded with the secretory cells: they are to be found in the neighbourhood of the veins in the leaves of *Aristolochia Galeottii*, Duch., *A. passifloraefolia*, A. Rich., *A. veraguensis*, Duch. and *Holostylis reniformis*, Duch.

Groups of cells with **silicified walls** are very widely distributed in this Order, having been observed in *Holostylis* and in 94 species of *Aristolochia*. The silicification usually involves a group of cells belonging to the upper epidermis of the leaf, and the subjacent cells of the palisade-tissue; the contiguous walls of these two layers are silicified, more or less strongly thickened, and sometimes stratified (Fig. 166, *D–F*). Silicified groups of cells are of rarer occurrence (*Aristolochia acutifolia*, Duch., Fig. 166, *G*) in the interior of the leaf; they form spherical or hemispherical groups, in which those portions of the walls abutting on one another at the centre as well as the radial walls are thickened and silicified. The silicified groups of cells are generally visible even with a lens as white or lustrous elevations on the upper surface of the leaf, and resemble pustules; occasionally they give rise to transparent dots in the leaf. Silica also occurs under another form in this Order, viz. as plugs filling the cavities of the cells; these were present in all species of the genera *Thottea* and *Apama*, which I examined (Fig. 166, *H–J*). The siliceous cells[1] of *Thottea* and *Apama* are found in the leaf for the most part immediately beneath the upper and lower epidermis, and occasionally in the middle of the mesophyll as well; in *Thottea grandiflora*, Rottb. they also occur in the hypoderm. They have also been met with in the primary cortex of *Thottea grandiflora*, *T. tricornis*, Maing. and *Apama siliquosa*, Lam., either in a subepidermal position or at a greater depth in the tissue.

Oxalate of lime is excreted chiefly in the form of small prismatic or acicular crystals, and as clustered crystals; large ordinary solitary crystals are very rare (in the neighbourhood of the vascular bundles of the veins in *Aristolochia reticulata*, Nutt.). In *Asarum*, *Saruma*, *Thottea*, *Holostylis* and most of the species of *Apama* the small crystals only have been observed. They are commonly accompanied by clustered crystals of varied size in the species of *Aristolochia*, and small clustered crystals are also found in the palisade-tissue of *Apama corymbosa* (Griff.).

Regarding the **hairy covering**, two features have been sufficiently indicated above as important: the absence of glandular hairs and the occurrence of bracket-hairs. The ordinary form of clothing hairs in this Order is that of simple, uniseriate trichomes, which exhibit a number of differences in the thickness of their walls and in the number and length of the component cells. The following forms of these hairs require special mention: the narrow whip-shaped trichomes of certain *Aristolochias* (*A. barbata*, Jacq., *A. costaricensis*, Duch., &c.); the trichomes found in the species of *Apama* and distinguished by having several relatively short basal cells and a few long terminal cells; and the curious trichomes of *Saruma Henryi*, Oliv., which are rather thin-walled, and have an elongated terminal cell with doubly refractive, finely granular contents[2]. The above-mentioned bracket-hairs generally consist of a fairly

[1] In my paper on the anatomy of the Aristolochiaceae these cells were described as secretory sacs.

[2] As proved by their chemical behaviour towards acetic, hydrochloric and sulphuric acids, these contents include fine crystal-sand composed of oxalate of lime, and this constitutes the doubly refracting portion.

high, unicellular, dome-shaped pedestal, which is seated on the epidermis, a short neck-cell, and a terminal cell, bent like a hook, the tip being in most cases solid and silicified (Fig. 166, *K*). When the pedestal is high, it is generally composed of a rather large number of cells. In this case it consists of tiers, which are either unicellular throughout (*A. eriantha*, Mart. et Zucc.), or multicellular in the lower portion of the pedestal (*A. pubescens*, Willd.); or in other cases there is a double pedestal (*A. auricularia*, Boiss.) consisting of a broad base, the tiers of which are multicellular, surmounted by a long uniseriate pedestal bearing the terminal cell. In the bracket-hairs of certain species of *Aristolochia* (*A. auricularia*, Boiss., *A. Chamissonis*, Duch., *A. cretica*, Lam.,

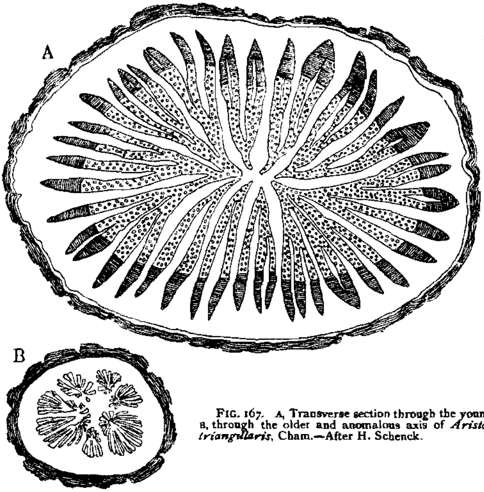

FIG. 167. A, Transverse section through the young, and B, through the older and anomalous axis of *Aristolochia triangularis*, Cham.—After H. Schenck.

A. hirta, L., *A. nervosa*, Duch.) the hooked terminal cells are replaced by others which are pointed, or only show a tendency to assume the shape of a hook ('undeveloped bracket-hairs').

The **petiole** has been investigated in *Asarum canadense* and in a few *Aristolochias* by Petit, and in these cases three vascular bundles pass into it. In *Asarum canadense* they run through the entire petiole; in *Aristolochia*, on the other hand, their number is increased by branching, so that the characteristic region exhibits an arc of a relatively large number of approximated or isolated vascular bundles.

3. STRUCTURE OF THE AXIS. The structure of the axis is generally normal in this Order. The broad primary **medullary rays**, which are composed of lignified or unlignified cells, are especially characteristic; they separate the vascular bundles from one another in the woody species of the genera *Aristolochia*, *Apama* and *Thottea*, as well as in the rhizome of *Asarum*. In the woody species of *Aristolochia* they extend for long distances through the stem, and are only traversed by strands of woody tissue at a few points (Strasburger).

In some cases (e.g. the woody Aristolochias), in the course of growth in thickness, broad secondary medullary rays are successively developed in the vascular bundles themselves, occasioning a dichotomous fission of the plates of wood and bast composing the vascular bundles ; in this way we obtain a characteristic appearance in transverse section, which H. Schenck has termed the *Aristolochia*-type. This is specially distinct in young stems of *A. triangularis*, Cham. (Fig. 167, *A*), in which the medullary rays are no narrower than the rays of wood between them ; the same structure is less typically differentiated in *A. Sipho*, *A. tomentosa* and other species, in which the wood has a denser structure.

The **pith** commonly consists of unlignified cells in *Aristolochia*, of lignified cells in *Thottea* and *Apama*.

The following facts may be mentioned regarding the structure of the **wood**, more especially that of the woody species of *Aristolochia*, *Thottea* and *Apama*. The vessels attain a considerable diameter (as much as ·14 mm.) in the twining species ; their perforations are simple throughout (even in *Asarum*). The wood-parenchyma is usually scantily developed, but is more abundant in *Apama siliquosa*, Lam. and *Thottea grandiflora*, Rottb., where it occurs in rows accompanying the tracheae. The walls of the wood-prosenchyma bear large bordered pits in *Aristolochia*, small but distinct bordered pits in *Apama* and *Thottea*. Spiral thickening has been observed in the narrower vessels and in the prosenchyma (with bordered pits) of *A. tomentosa*, L. In the rhizome of *Asarum* the xylem contains no prosenchyma, and is composed of unlignified parenchyma and vessels only.

The first feature to be described in the structure of the **cortex** is the origin of the cork ; this is only known in *Aristolochia*, where the cork arises superficially, mostly in the subepidermal layer of cells. The cork of *Aristolochia* is composed of alternating layers of thin-walled cubical cork-cells, and cells with cellulose walls. *Asarum europaeum* develops no cork ; the outer layers of the cortex simply become suberized and subsequently peel off. Stone-cells are sometimes found in the primary cortex. In *Aristolochia*, *Apama* and *Thottea* the outer portion of the pericycle contains a closed or locally interrupted composite sclerenchymatous ring, the fibrous cells of which have rather wide lumina, and are to some extent septate by means of thin transverse walls ; the inner parenchymatous portion of the pericycle is often strongly developed. In the rhizomes of *Aristolochia* and *Asarum* the sclerenchymatous ring is replaced by an endodermis. The secondary bast never contains bast-fibres, though stone-cells may be present. The sieve-tubes often have wide lumina, and the sieve-plates are commonly provided with coarse pores.

Anomalous structure of the axis is only[1] found in *Aristolochia triangularis*, Cham., according to H. Schenck (Fig. 167, *B*). It first appears in stems of this species 3·5 cm. in thickness. By secondary dilatation of the pith the vascular ring first becomes divided up into eight fan-shaped xylem-segments corresponding to its eight component bundles ; 'narrow secondary plates of wood and bast are formed, spreading out like a fan, from the sides of the xylem-segments, and extending round their inner angles, these plates being derived from a cambium, which appears in immediate contact with the original segments of the wood.'

Literature : Mohl, Bau u. Winden d. Ranken- u. Schlingpfl., Tübingen, 1827, p. 97 and Tab. xi.

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[1] The stem of the plant, described as '*Aristolochia biloba*' by Schleiden and De Bary, and stated to possess successive rings of growth, is normal in structure (see Solereder, 1889). So also is the axis of *Bragantia Wallichii* (*Apama siliquosa*); the stem described under this specific name by Masters is provided with successive rings of growth of the Menispermaceous type, but belongs to a species of *Gnetum* (see Solereder, 1894).

—Decaisne, Lardizabalées, Arch. Mus. d'hist. nat., t. i, 1839, p. 143 et seq.—Griffith, in Transact. Linn. Soc. of London, vol. xix, 1842, p. 334.—Lindley, Veg. Kingd., 1846, p. 792.—Schleiden, Grundz. d. wiss. Bot., ii, 1850, p. 167 and Fig. 152.—Duchartre, Végét. et struct. anat. des A., Compt. rend., t. xxxviii, 1854, p. 1142 et seq.—Vaupell, Peripher. Wachst. d. Gefässb., Leipzig, 1855.—Masters, Struct. affin. and distrib. of the genus *Aristolochia* etc., Journ. Linn. Soc., vol. xiv, 1875, p. 487 et seq.—De Bary, Vergl. Anat., 1877.—Zacharias, in Bot. Zeit. 1879, p. 633.—Möller, Rindenanat., 1882, pp. 124-5.—Mentovich, Mark, Klausenburg, 1885, Hungarian; abstr. in Just 1885, i, p. 789.—Hérail, Tige des Dicot., Ann. sc. nat., sér. 7, t. ii, 1885, pp. 248-51 and pl. 17.—Solereder, Holzstr., 1885, pp. 222-3.—Douliot, Périderme, Ann. sc. nat., sér. 7, t. x, 1889, pp. 332-3.—Petit, Pétiole, Act. Soc. Linn. de Bordeaux, t. 43, 1889, p. 19 and pl. i.—Solereder, Vergl. Anat. d. A., Engler, Bot. Jahrb., Bd. x, 1889, pp. 410-524 and Tab. xii-xiv and in Natürl. Pflanzenfam., iii. Teil, Abt. 1, 1889, p. 266-7.—Planchon, Les Aristiloches, Montpellier (Hamelin Frères), 1891, 266 pp.—Strasburger, Leitungsbahnen, 1891, pp. 256-66.—H. Schenck, Anat. d. Lianen, 1893, pp. 154-5 and Tab. viii.—Solereder, in Bull. de l'Herbier Boissier, t. ii, 1894, pp. 384-6.—[Bastin, Struct. of *Asarum canadense*, Americ. Journ. of Pharm. 1894 (see also the pharmacognostic works with regard to the mostly obsolete rhizome and root of species of *Aristolochia* and *Asarum*).—Schwabach, Mech. Ring, Bot. Centralbl. 1898, iv, p. 354 et seq.]

PIPERACEAE[1].

1. REVIEW OF THE ANATOMICAL FEATURES. With the exception of the genus *Symbryon*, the members of this Order are distinguished by the possession of secretory cells, which very commonly give rise to a transparent dotting of the leaves; besides these, lysigenous mucilage canals occur in the pith of the stem of *Piper*. The stomata are only found on the under side of the leaf, and are invariably surrounded by a considerable number of epidermal cells, which are sometimes arranged in a rosette. Both scalariform and simple perforations have been observed in the vessels. The wood-prosenchyma, when present, bears simple pits. Where formation of cork takes place it is superficial. Four types may be distinguished in the arrangement of the vascular bundles in the stem (Fig. 169): I. The Saurureae (*Saururus*, *Houttuynia* and *Anemiopsis*) have a normal ring of vascular bundles. II. The stem of *Verhuellia* only contains a single vascular strand, which is concentric in structure. III. The species of *Piper* (incl. *Heckeria* and *Macropiper*) have medullary vascular strands in addition to a peripheral ring of bundles; the peripheral ring is characterized by secondary growth by means of a cambium, and by broad primary medullary rays, and is separated from the pith by a sclerenchymatous ring; the medullary bundles in most cases only have slight growth in thickness, and are arranged in one or more circles. IV. In *Peperomia* the vascular bundles are scattered in the ground-tissue and only exhibit slight growth in thickness. The hairy covering is constituted by (*a*) simple, uniseriate hairs; (*b*) small structures, which are composed of a limited number of cells and resemble glandular hairs (*Saururus*, *Peperomia*, *Piper*); and (*c*) unicellular pearl-glands (*Piper*); a dense hairy covering is not present in most cases. Oxalate of lime is generally excreted in the form of small acicular crystals, or of small, sometimes minute, sand-like crystalline bodies of varying shape, or as clustered crystals; in *Symbryon* clustered crystals are found in the epidermis of the leaf, whilst ordinary large solitary crystals occur in the mesophyll. The following anatomical features are of value for special diagnosis in this Order: the occurrence of a hypoderm composed of a varying (often large) number of layers on the upper side of the leaf (*Piper*, *Saururus*, *Anemiopsis*, and especially *Peperomia*); silicification of epidermal cells in the leaf (species of *Piper*); papillose differentiation of the epidermis of the leaf (*Peperomia marmorata*); varying differentiation of the pericycle and of the layer of collenchyma in the primary cortex of the stem in the species of *Piper*, and so on.

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[1] For the genus *Lactoris*, which is included amongst the Piperaceae by Bentham and Hooker, see Lactoridaceae, p. 39.

2. Structure of the Leaf. The leaves of the species investigated are bifacial in structure in all cases. The **stomata** (*Anemiopsis, Peperomia, Piper, Saururus*) are found exclusively on the lower side of the leaf, and are surrounded by several ordinary epidermal cells, or by a rosette of subsidiary cells arranged according to the Cruciferous type (species of *Piper* and *Peperomia*, according to Benecke). Beneath the upper epidermis of the leaf a **hypoderm** of one or more layers has been observed in all the species of *Peperomia* hitherto investigated (by Treviranus, Payen, Pfitzer, Beinling and Haberlandt), in *Chavica maculata* (Treviranus), in *Artanthe colubrina*, Miq. (Payen) and also in *Saururus cernuus*, L., *Piper Khasianum*, C. DC., *P. Zuccarinii*, C. DC.[1] and *Anemiopsis californica*, Hook. et Arn. (according to my own observation).

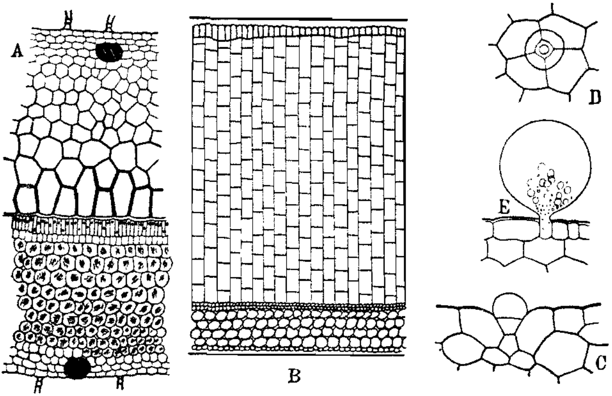

Fig. 168. A, Transverse section of the leaf of *Peperomia incana*, Dietr. B, Transverse section of the leaf of *P. pereskiaefolia*, H.B.K. C–D, Hydathodes of *P. incana*. E, Pearl-gland of *Artanthe* sp.—B after Pfitzer, E after Nestler, the remainder original.

The hypoderm of the genus *Peperomia* has been examined in some detail by Pfitzer. The number of component layers varies, and is often very considerable; in *P. arifolia*, Miq., the hypoderm consists of a single layer of cells; in *P. blanda*, H.B.K., of 1–3; in *P. incana*, Dietr. (Fig. 168, *A*) of 6–7 or more; in *P. pereskiaefolia*, H.B.K. (Fig. 168, *B*) of 14–15 layers. Owing to the large number of layers and the size (which is often considerable) of the cells in the inner layers, the epidermis and the subjacent hypoderm attain such dimensions that the two together in *P. incana* are thicker than the whole of the remaining portion of the fleshy leaf, whilst in *P. magnoliaefolia*, Dietr. and *P. rubella*, Hook. they exceed it several times in thickness, in *P. pereskiaefolia* seven times. According to Pfitzer, the hypoderm in *Peperomia* is developed from a single-layered epidermis. In some cases, viz. when cell-division and growth take place equally in the individual layers of the entire integumental tissue, this mode of origin can still be recognized in the mature leaf, the cells of the epidermis and those of the hypodermal layers being arranged in rows at right angles to the surface of the leaf as seen in a transverse section (*P. arifolia*). In *P. pereskiaefolia* all of the numerous hypodermal cells coincide vertically, whilst the

[1] It may be mentioned here that the conjecture expressed in the Kew Index that *Piper Zuccarinii* might be a species of *Pothos* has become untenable since the finding of the type-specimen in the Herb. Monac.

epidermis consists of smaller cells in consequence of secondary vertical divisions having taken place. In other cases (*P. incana*) this arrangement is no longer recognizable; the outer portion of the hypoderm consists of cells with small lumina, the inner of cells with larger lumina. The hypodermal cells, in agreement with their function as water-reservoirs, have contents consisting of watery cell-sap, rarely including a few chlorophyll-grains. The cell-walls are mostly thin, but in *P. incana* they are thick in the inner layers of the hypoderm; they are distinctly collenchymatous in *P. magnoliaefolia*.

In those species in which there is no hypoderm, the single-layered epidermis of the leaf often consists of large cells. The spongy tissue also takes part in the storage of water in the *Peperomias*, and consequently contains little chlorophyll. Sclerenchyma has been observed accompanying the vascular bundles of the **veins** in the genus *Symbryon* only. The following are special features in the structure of the leaf: silicification of the **epidermis** (*Piper colubrinum*, Link, *P. elongatum*, C. DC. and *P. Betle*, L. according to Engler, *P. hirsutum*, Sw. and *P. Hostmannianum*, C. DC. according to my own observations); papillose differentiation of the epidermal cells on both sides of the leaf in *Peperomia marmorata* (Beinling); spots with a silvery sheen on the upper side of the leaf in *Peperomia* '*argyracea*, Hort. Bonn.' (=? *P. argyrea*, Hort.), these being due, according to Pfitzer, to a similar cause to those of the *Begonias*, i.e. to intercellular spaces, which starting from the palisade-tissue penetrate between the inner cells of the hypoderm and extend to about the middle of this tissue; finally, the corky excrescences on the leaves of *Peperomia maculosa* and *P. obtusifolia* (E. Bachmann).

The **hairy covering** is dense in rare cases only. It is composed of clothing hairs, small glands and pearl-glands. The clothing hairs are uniseriate, of varying length, and have wide lumina. Small glands have been observed in species of *Saururus*, *Peperomia* (Fig. 168, *C–D*) and *Piper*; they consist of a basal cell, belonging to the epidermis, a short stalk-cell, and a hemispherical, spherical or sac-like terminal cell, which in the last case frequently lies upon the surface of the epidermis. In the trichomes in question either no secretion at all is produced, or only a small amount is formed beneath the cuticle of the terminal cell. As Haberlandt suggests, they probably in all cases serve for the excretion of water (as hydathodes), or at least for the absorption of water. The pearl-glands [1] (Fig. 168, *E*), first observed by Meyen and subsequently examined more thoroughly especially by Penzig and Nestler, only appear temporarily and under certain conditions; they often have the form of large glistening spherical bodies (1 mm. or more in diameter) occurring in moderate numbers on all the aerial parts of the plant, while they are more numerous on the stem and petiole. They consist of a single large cell, the narrow base of which is inserted in the epidermis. Owing to the abundance of plastic nutritive substances (proteid and fatty oil) which they contain, the readily deciduous pearl-glands are regarded biologically as small food-bodies.

The usual form of excretion of **oxalate of lime** in this Order (*Saururus*, *Peperomia*, *Piper* with *Macropiper*, and *Heckeria*) is constituted by small acicular crystals, sometimes (*Piper peltatum*, L.) resembling raphides, and small crystalline bodies of a different shape, sometimes even so finely divided as to be like sand. In addition to these crystalline elements, which occur in all parts of the plant, and are frequently found in extraordinary abundance, clustered crystals are present in the axis (pith and primary cortex) of *Saururus cernuus*, L., and in the mesophyll of the *Peperomias*. The genus *Symbryon* differs

[1] The pearl-glands are described: by Meyen in *Piper spurium*; by De Bary in *P. nigrum*, *Enckea glaucescens* and *Artanthe elongata*; by Nestler in *Artanthe* '*cordifolia*,' Miq. (= ? *A.*

from the other members of the Order in the features presented by its crystals: the veins of the leaf of *S. tetrastachyum*, Griseb. contain ordinary large solitary crystals, which have not been observed elsewhere in the Order, whilst both the upper and lower epidermis include small cells mostly united in groups, and filled with small clustered crystals.

Two kinds of **internal secretory organs** are found in the Piperaceae, viz.: (*a*) secretory cells, occurring in the leaf and axis, and, in the former, giving rise to transparent or opaque dots, according to the nature of the secretion, and (*b*) mucilage-canals, which only occur in the axis. The secretory cells have been shown by Bokorny to occur in the leaf of numerous species of *Saururus*, *Piper* and *Peperomia*, and according to my own observations they are also present in the monotypic genus *Zippelia* and in *Anemiopsis* (*A. californica*, Hook.); they are wanting in *Symbryon* only [1]. In the leaf the secretory cells appear in the various tissues, e.g. in *Piper Hostmannianum*, C. DC. and *P. hirsutum*, Sw. in the mesophyll only, in *Saururus cernuus*, L. in the mesophyll and in the lower epidermis of the leaf, in *Anemiopsis californica*, Hook. in the mesophyll and in both the upper and lower epidermis. In the axis they occur in the pith, bast and primary cortex. The secretory cells mostly have a spherical shape. Their walls are suberized, and their contents are generally clear, more rarely (in the 'folia nigro-punctata' of *Peperomia melanostigma*, Miq., *P. nigro-punctata*, Miq. and *P. hirsutum*, Sw.) of a brown colour. There are other elements which must not be confounded with these spherical brown cells which replace the clear secretory cells, viz. cells filled with brown contents but not differing from the ordinary cells of the mesophyll in shape; such cells may be observed, for example, in the dried leaf of *Piper cernuum*, Vell. and *Saururus cernuus*, L.; in the living leaf their contents (at least in *Saururus*) are clear and strongly refractive. Mucilage-canals have only been observed in species of *Piper* (*Artanthe Zacuapana*, 'Cham. et Schlecht.' = *Piper tiliaefolium*, Cham. et Schl. according to Debray, *Piper fluminense*, C. DC. according to H. Schenck, and *P. Carpunya*, R. et P., *P. Khasianum*, C. DC., *P. nepalense*, Miq., *P. nigrum*, L. and *P. Zuccarinii*, C. DC. according to my own investigation). Either one or several of them occur in the pith; they have wide lumina, and without doubt have a lysigenous origin.

3. Structure of the Axis. In the structure of the axis, which has been examined especially by C. de Candolle, J. E. Weiss and Debray, we may distinguish four types, requiring separate description.

The **first type** is found in the genera *Saururus*, *Houttuynia* and *Anemiopsis*, which are members of the tribe Saurureae; in this type a normal ring of vascular bundles is present. The bundles lie isolated in the parenchymatous ground-tissue of the stem, and are as a rule about equidistant from the centre; but in the case of *Saururus* those bundles which are the next to bend out into the leaves, project a little further towards the exterior of the transverse section.

As an example of this type the stem-structure of *Saururus cernuus*, L. may be described in somewhat greater detail. In this plant, which grows in marshy localities, the pith, containing numerous rather large intercellular spaces, is surrounded by a ring of vascular bundles; these bundles may be shortly described as embedded in a ring of sclerenchymatous fibres. Thus each vascular bundle is surrounded by a ring of sclerenchyma, thicker on the outer than on the inner side of the bundle, and the outer parts of these sclerenchymatous rings are connected with one another by narrow bridges of the same tissue. The xylem in the vascular bundles of *Saururus* consists of primary tracheae, pitted vessels and lignified parenchyma; the pitted

[1] Secretory cells are present in the three species of *Piper* (*P. auritum*, H.B.K., *P. cernuum*, Vell. and *P. Enckea*, C. DC.), in which Bokorny states that they are absent.

vessels attain a diameter of ·075 mm., and exhibit scalariform perforations with many bars; they bear scalariform bordered pits where they are in contact with other vessels, and relatively large simple pits in contact with parenchyma. Certain portions of the primary cortex show rather large intercellular spaces.

Verhuellia belongs to the **second type**. Although it is not aquatic, this genus, like certain dicotyledonous water-plants, possesses only an axile strand, sympodial in structure and consisting of weak and very closely approxi-

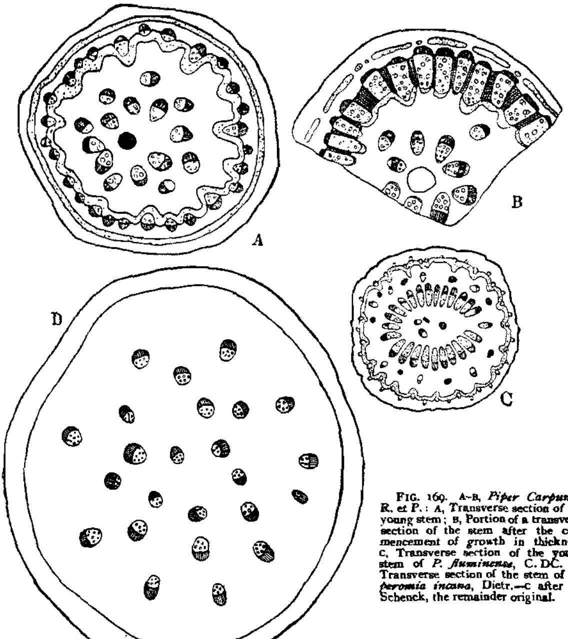

FIG. 169. A–B, *Piper Carpunya*, R. et P.: A, Transverse section of the young stem; B, Portion of a transverse section of the stem after the commencement of growth in thickness. C, Transverse section of the young stem of *P. fluminense*, C. DC. D, Transverse section of the stem of *Peperomia incana*, Dietr.—C after H. Schenck, the remainder original.

mated leaf-traces, which are fused longitudinally. The axile strand appears to be concentric, according to Schmitz's brief statements.

The **third type** (Fig. 169, *A–B*) is constituted by the genus *Piper* in the wider sense, including *Heckeria* and *Macropiper*. In this case two kinds of vascular bundles are present. The one kind forms a peripheral circle, in which the bundles are distinct from one another in the young stem (Fig. 169, *A*), and are applied to a sclerenchymatous zone limiting the pith externally and generally having an undulated course; after the commencement of activity of the cambial ring (Fig. 169, *B*) these bundles grow in thickness and become separated from one

another by broad primary medullary rays. Those of the second kind are medullary vascular bundles, which lie isolated in the pith and are arranged more or less distinctly in one or more rings; as a rule they only exhibit a limited growth in thickness by means of strips of cambium of the same breadth as the vascular bundles.

The following statements regarding the detailed structure of the stem of *Piper* may be quoted (chiefly from J. E. Weiss). The formation of cork takes place in the epidermis (*P. Carpunya*, R. et P., *Chavica Roxburghii*, Miq.), or in the outermost cell-layer of the primary cortex (*Artanthe* '*cordifolia*,' Miq.,[1] *Piper bullatum*, Vahl, *P. geniculatum*, Sw.). The primary **cortex** contains either a collenchymatous ring or isolated bundles of collenchyma. In certain species (*Piper bullatum*, *P. geniculatum*, *P. peltatum*, L.) the collenchyma retains its character, even in the older branches; in others sclerenchymatous fibres in varying numbers develop in the collenchyma (*Artanthe cornifolia*, *Chavica Betle*, L., *C. Roxburghii*, *Piper Bredemeyeri*, Jacq.), or the whole of the collenchyma becomes transformed into a ring of sclerenchymatous fibres (*Piper Carpunya*, *P. rivinoides*, Kth.), which subsequently becomes ruptured in the course of growth in thickness. In the older branches of *Piper nigrum*, L. I found isolated bundles of sclerenchymatous fibres, which were to some extent united by sclerosed parenchyma. The innermost portion of the primary cortex is formed by an endodermis, which either surrounds the entire peripheral ring of vascular bundles (*Artanthe cornifolia*, *Chavica Betle*, &c.), or is only developed in contact with the bast of the bundles (*Piper Carpunya* . Towards the pith the **peripheral ring of bundles** rests against the inner sclerenchymatous sheath mentioned above; this sheath is either entirely composed of sclerenchymatous fibres, or is parenchymatous opposite the primary medullary rays; it is continuous in the young branch, but becomes split up into fragments after the commencement of growth in thickness. Corresponding to this inner sheath there is frequently a sclerenchymatous layer at the outer margin of the groups of bast; it is either developed in the form of semilunar bundles of fibres united into a ring by groups of sclerosed parenchymatous cells (*Piper nigrum*), or it is represented by semilunar groups of hard bast alone (*Artanthe cornifolia*, *Chavica Betle*, &c.) or by a few bast-fibres (*Piper Carpunya*, &c.), whilst in *Piper bullatum*, for example, it is absent. The growth of the peripheral zone of vascular bundles takes place by means of a cambial ring, which produces primary medullary rays, 10–16 cells in breadth, between the bundles; these medullary rays traverse the internodes in the form of longitudinal plates and are composed of cells only slightly elongated in the vertical direction. The xylem-portions of the vascular bundles, apart from the primary tracheae, which are enclosed in thin-walled parenchyma, consist chiefly of the following elements: (*a*) pitted vessels, having mostly simple, more rarely (according to Debray) also scalariform perforations with few bars; (*b*) wood-prosenchyma bearing simple pits, and sometimes septate by means of thin transverse walls; and (*c*) secondary, generally broad, medullary rays (of the *Aristolochia*-type). The **medullary vascular bundles** are embedded in a thin-walled pith and are of the nature of leaf-traces; they are collateral in structure, and their wood and bast are generally normally orientated. They are either arranged in a single, more or less regular ring (*Piper Bredemeyeri* *Chavica Betle*, &c.), or in two (*Piper geniculatum*) or even more rings (*P. bullatum* with about 25 vascular bundles in the pith). The xylem in these bundles has the same composition as that of the peripheral bundles; groups of sclerenchymatous fibres are frequently developed at the inner margin of the xylem

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[1] No doubt *Artanthe cornifolia*, Miq. is the plant referred to. The incorrect name '*A. cordifolia*' seems to be widely spread in gardens (cf. footnote, p. 690).

and at the outer margin of the bast. The growth in thickness of these bundles is often very considerable (especially in *P. geniculatum* and *Chavica frustrata*, Miq.).

According to H. Schenck, the stem-structure of *Piper fluminense*, C. DC. deviates somewhat from that of the other species of the genus. The young stem (Fig. 159, *C*) has, as its essential feature, two rings of vascular bundles, of which, curiously enough, the bundles composing the peripheral ring and resting against the sclerenchyma are very small, while the bundles forming the medullary ring are much larger. In the older stem (5 cm. in diameter) the bundles of both rings are found to have grown in thickness individually, even the peripheral bundles growing by means of cambial strips, which do not unite to form a ring.

The genus *Peperomia* belongs to the **fourth type**, in which the vascular bundles are scattered in the ground-tissue (Fig. 169, *D*). Regarding the detailed structure of the stem of *Peperomia*, the following statements may be made on the authority of J. E. Weiss and from my own investigation of *P. carthaginensis*, C. DC. The epidermis is simple (*P. rubella*), or consists of two layers (*P. variegata*, R. et P. &c.). The cork arises in the epidermis; when the latter consists of two layers, the cork develops in the outer layer (*P. carthaginensis*, *P. variegata*). Collenchymatous tissue is very strongly developed at a depth of a few layers of cells beneath the epidermis. This is followed internally by parenchymatous ground-tissue, in which the vascular bundles are embedded. The number and mode of arrangement of the bundles varies. Their distribution is sometimes rather irregular, in other cases one can distinguish two or more rings of bundles; when two of these are present, the bundles composing them alternate in the transverse section. The bundles are generally collateral in structure, and their wood and bast is normally orientated. They are either of equal size, or the outer (*P. incana*, Dietr.) or inner bundles (*P. brachyphylla*, Dietr.) are the larger; in *P. verticillata*, Miq. there is a very large central vascular bundle, which has concentric structure (with central xylem) and may perhaps have arisen by the fusion of several bundles. The bundles are commonly provided with an endodermis, which either surrounds the whole bundle (*P. obtusifolia*, Dietr., &c.) or only forms a semicircle on the outer side of the bast (*P. urocarpa*, Fisch. et Mey., &c.); in other species, such as *P. amplexifolia*, Dietr., &c., the endodermis is absent. There are no sclerenchymatous elements in the vascular bundles. The bast is sometimes collenchymatous (*P. variegata*, R. et P.); the xylem consists of unlignified parenchyma and vessels. There is only slight growth in thickness.

Literature: Treviranus, in Verm. Schr. iv, 1821, p. 11 and Phys. d. Gew. i, 1835, p. 449.—Meyen, Sekretionsorg., 1837, p. 47.—Sanio, in Bot. Zeit. 1862, p. 213 and 1864, p. 27.—C. de Candolle, Mém. s. l. fam. d. P., Mém. Soc. de phys. et d'hist. nat. Genève, t. xviii, 2, 1866, 32 pp. and 6 Tab. and in DC. Prodr. xvi, 1, 1869, p. 235[65] et seq.—Pfitzer, Mehrsch. Epid. etc., Pringsheim Jahrb., Bd. viii, 1871–2, pp. 26–31 and Tab. vi.—Schmitz, Fibrovasalsyst. d. P., Diss., 1871 and *Verhuellia*, Flora 1872, p. 408.—J. E. Weiss, Wachstumsverh. etc. d. P., *Flora 1876*, p. 321 et seq. and Tab. xi–xii.—De Bary, Vergl. Anat., 1877; here on p. 260, footnote 2, further older literature.—E. Bachmann, Korkwuch., Pringsheim Jahrb., Bd. xii, 1879–81, p. 203 et seq.—Beinling, Anat. d. Laubbl. u. Wurz. von *Peperomia*, Cohn, Beitr. z. Biol., Bd. iii, Heft 1, 1879, pp. 32–7 and Tab. iv.—Zacharias, in Bot. Zeit. 1879, p. 624.—Bokorny, Durchs. P., Flora 1882, p. 365 et seq. and sep. copy, pp. 22–3.—Morot, Péricycle, Ann. sc. nat., sér. 6, t. xx, 1885, p. 268.—Solereder, Holzstr., 1885, pp. 223–4.—Debray, Caract. anat. et parcours des faisc. fibro-vasc. d. P., Paris (O. Doin), 1886, 107 pp. and 16 pl.; abstr. by Sanio, in Bot. Centralbl. 1886, ii, pp. 136–60.—Solereder, Sekretz. bei den P., Engler, Bot. Jahrb., Bd. x, 1887, pp. 509–11.—Benecke, in Bot. Zeit. 1892, p. 555 et seq.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 55–62.—Nestler, Perldrüsen von *Artanthe cordifolia*, Miq., Oesterr. bot. Zeitschr. 1893, pp. 332 and 386 et seq., Tab. xvi.—Penzig, Perldrüsen, Report of Congress, Genoa, 1893, p. 237 et seq. and Tab. xv.—H. Schenck, Anat. d. Lianen, 1893, pp. 42–5 and Tab. i.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 (1894), pp. 1 and 4–5.—Haberlandt, Trop. Laubbl. ii, Sitz.-Ber. Wiener Akad., Bd. ciii, Abt. 1, 1894, p. 521 et seq. and Tab. iii.—Virchow, Blattzähne, Archiv d. Pharm. 1896, sep. copy, p. 39.—[Jäderholm, Anat. stud. öfver sydamerik. Peperomier, Diss., Upsala, 1898, 99 pp., 2 Tab.]

CHLORANTHACEAE.

This Order is distinguished anatomically by the following characters: the possession of secretory cells; the exceptionally numerous bars in the perforations of the xylem-vessels; normal stem-structure; the absence of a hairy covering and the lack of a special type of stoma. The two genera *Chloranthus* and *Hedyosmum* (the third genus *Ascarina* has not been investigated) may be distinguished by the pitting of the wood-prosenchyma, which is typically bordered in *Chloranthus*, but simple in *Hedyosmum*, as well as by the occurrence (*Hedyosmum*) or absence (*Chloranthus*) of mucilage-canals at the margin of the pith.

The **secretory cells** were first observed by Blenk, according to whom they frequently give rise to transparent dots in the leaf. In the leaf, as far as I am aware, they are only present in the mesophyll, never in the epidermis. They are also found in the cortex and pith of the axis. They are spherical in shape and have a suberized membrane. They have been shown to occur in the two genera *Chloranthus* and *Hedyosmum* and will probably also be found in *Ascarina*, since the plants of this genus are described as aromatic.

Secretory organs of a different kind, viz. the **mucilage-canals** [1], referred to above, occur only in the species of *Hedyosmum*. I have met with these canals at the margin of the pith in *H. brasiliense*, Mart., *H. glabratum*, H.B.K. and *H. racemosum*, Don, and in a similar position in the petiole of *H. arborescens*, Sw.; they appear in the form of wide intercellular spaces, which are elliptical in transverse section and are apparently of schizogenous origin. Their contents consist of mucilage, which in *H. brasiliense* encloses sphaerocrystalline masses; the latter are insoluble in hot water, alcohol and ether, but readily soluble in hydrochloric acid.

I have examined the structure of the **leaf** in *Hedyosmum brasiliense*, Mart., *H. arborescens*, Sw. and *Chloranthus brachystachys*, Bl. In these species it is bifacial, though typical palisade-parenchyma composed of long cells does not occur. The latter is replaced by short-celled arm-palisade (of Haberlandt). The spongy tissue has large intercellular spaces. The stomata are only found on the lower side of the leaf, and no definite type of stoma is evident. But in *H. arborescens* the neighbouring cells are marked by their arrangement in a rosette, and in *Chloranthus brachystachys* one or two subsidiary cells, parallel to the pore, may be seen here and there. In *H. arborescens* there is a single layer of hypoderm beneath the epidermis on the upper side of the leaf. The vascular bundles of the veins are provided with a sclerenchymatous sheath.

The structure of the **wood** has been examined in *Hedyosmum brasiliense*, Mart., *H. arborescens*, Sw., *H. racemosum*, Don, *Chloranthus brachystachys*, Bl. and *C. officinalis*, Bl. The medullary rays of the wood are occasionally very broad (e.g. in *H. brasiliense*), in other cases less so; their cells are always considerably elongated in the vertical direction. The diameter of the vessels is not great (reaching ·045 mm.); in branches of *Chloranthus brachystachys* from herbarium-material the pitted vessels are confined to the neighbourhood of the primary wood. Scalariform perforations, with very numerous bars, are highly characteristic of the Chloranthaceae; in *H. brasiliense* and *H. racemosum* as many as 100 bars may be counted on the same perforation. In contact with parenchyma the walls of the vessels are furnished with bordered pits. The wood-prosenchyma bears typical, large bordered pits in *Chloranthus*, whilst in *Hedyosmum* the elements of this tissue have simple pits, and are frequently provided with delicate transverse walls.

In order to be able to add some information regarding the structure of

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[1] Engler's statement, that the species of *Hedyosmum* are characterized by gelatinization of their medullary tissue, is inaccurate.

the **cortex**, I examined the latter in *Chloranthus brachystachys* and *Hedyosmum brasiliense*. No formation of cork was observed. In *Chloranthus brachystachys* the outer limit of the bast is formed by a composite and continuous sclerenchymatous ring composed of groups of bast-fibres and of sclerosed parenchymatous cells with wide lumina; in *H. brasiliense* isolated groups of sclerenchymatous fibres alone occur in this region. In this species the outer portion of the primary cortex is differentiated as typical collenchyma, and the epidermis is subpapillose.

The occurrence of silicified groups of cells in the leaf of *H. brasiliense* and *H. arborescens* deserves special notice. The silicification involves a group of epidermal cells and the mesophyll-cells lying beneath them. Similar silicified cells have also been observed in the cortex of *Hedyosmum brasiliense* in the neighbourhood of the primary groups of hard bast. Crystalline elements were entirely absent in the leaves examined. In the pith and the inner portion of the primary cortical parenchyma of *H. brasiliense* numerous small clustered crystals were observed, but nowhere else.

Literature: Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 19 and 315.—Blenk, Durchs. P., Flora 1884, p. 372 and sep. copy, p. 84.—Solereder, Holzstr., 1885, pp. 224-5.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1, p. 12.

MYRISTICACEAE.

The following anatomical features are characteristic of this Order: secretory cells; the excretion of oxalate of lime in the form of small acicular crystals, which are accompanied by clustered crystals; the absence of glandular hairs (?), and the occurrence of extremely characteristic trichomes, resembling stellate hairs and composed of one- or two-armed cells; stomata with two subsidiary cells, arranged parallel to the pore; the tendency to the formation of scalariform perforations in the vessels; the simple pitting of the wood-prosenchyma; the superficial formation of cork; the occurrence of isolated groups of hard bast in the pericycle, and the development of secondary hard bast.

The **secretory cells**, which like those of the preceding Orders frequently give rise to pellucid dots in the leaf, have been shown by Blenk to occur in the leaf of a large number of species. They are, however, also found in the axis, being situated in the pith, bast and primary cortex. The secretory cells of the leaf never occur in the epidermis, but are restricted to the mesophyll; where they occur in the palisade-parenchyma, they are mostly found only in the inner layer of this tissue, though exceptionally (*Iryanthera macrophylla*, Warb.) they may lie immediately beneath the upper epidermis. The secretory cells are spherical in shape; their contents are semi-fluid in some cases, whilst they are solid, crystalline and doubly refractive in others. The colour of the secretion may be either yellow or reddish, in a few cases deep brown, or almost black. In some species the secretion had entirely or partially disappeared in herbarium material. When treated microchemically, the walls of the secretory cells in the leaf of *Myristica officinalis*, Mart. show distinct differentiation into an outer suberized and an inner cellulose lamella. In *M. Horsfieldii*, Bl. (= *Horsfieldia Iryaghedhi*, Warb.) and *M. Vrieseana*, Miq. (= *H. Irya*, Warb.), according to Blenk, the membranes of the secretory cells in the leaf are strongly thickened and gelatinized; in water they swell up to such an extent that they appear to dissolve, and in this way the resinous contents are forced out of the secretory cells [1].

[1] For information regarding the secretory cells occurring in other parts of the plant see Voigt, Bau u. Entwickl. d. Samens u. Samenmantels von *Myristica fragrans*, Diss., Göttingen, 1885; Tschirch, Inhaltsst. des Arillus von *Myristica fragrans*, Ber. deutsch. bot. Gesellsch. 1888, p. 138 et seq. and Warburg, Monogr., loc. cit.

In many members of the Order, besides the secretory cells, there are elongated sacs having brown or red tanniniferous contents and occurring at the margin of the pith and in the secondary bast of the branch, as well as in corresponding positions in the veins of the leaf; these elements are generally distinguished from the neighbouring cells by having larger lumina, and they recall the well-known tannin-sacs. In the living plant their contents are aqueous or bright yellow, but become red on exposure to the air.

I have examined the **leaf-structure** especially in *Virola officinalis*, Warb., and a few statements on this subject have also been made by Blenk, Prantl and Warburg. In the species just mentioned the leaf has bifacial structure, and the palisade-tissue consists of several layers of long cells. The epidermal cells on both sides of the leaf have small polygonal outlines. Hypoderm is mentioned by Warburg as occurring on the upper side of the leaf in *Dialyanthera*. According to Blenk, the lower epidermis of the leaf commonly exhibits a more or less papillose differentiation. According to my own observations, distinct papillae are found in *Virola officinalis*, whilst in *V. sebifera*, Aubl. the lower epidermal cells are merely arched outwards. In *V. officinalis* and *V. sebifera* the stomata are confined to the lower surface of the leaf; in both species a single subsidiary cell is placed parallel to the pore on either side of the pair of guard-cells. In *V. officinalis* the smaller veins show a tendency to be vertically transcurrent by means of unlignified tissue; no sclerenchyma is developed in connexion with them, and the same applies to the larger veins. Warburg describes sclerenchymatous fibres, running irregularly through the mesophyll, in the genus *Gymnacranthera*, and branched spicular cells, frequently of stellate form, in species of *Iryanthera*, especially *I. macrophylla*, Warb.

The following statements regarding the structure of the **wood** are based on Warburg's work and on my investigation of *Virola officinalis* and *V. sebifera*. The medullary rays are narrow, being from one to two cells in breadth. The vessels are for the most part arranged radially in the transverse section of the axis, and attain a diameter of ·06–·1 mm. The perforations of the vessels are chiefly scalariform with 1–8 bars, but, besides these, simple, elliptical or circular perforations are also present. In contact with parenchyma the walls of the vessels show all transitions from large simple pits to bordered pits. The wood-parenchyma is scantily developed; the wood-prosenchyma bears simple pits and is locally septate by means of delicate transverse walls.

The structure of the **cortex** has been examined by Möller in rather old portions of the bark of *V. sebifera*, and by me in branches from herbarium-material of *V. officinalis*. The cork arises superficially in *V. officinalis*, viz. in the second layer of the primary cortex, and includes cells sclerosed on one side. In the same species the outer limit of the bast is occupied by isolated groups of primary bast-fibres. In the inner portion of the primary cortex there are groups of lignified cells corresponding in position to the interspaces between the groups of bast-fibres just mentioned. The occurrence of secondary hard bast is especially noteworthy, and could be determined even in herbarium-material of *V. officinalis*. In older specimens of the cortex (*V. sebifera*) the secondary groups of bast-fibres combined with stone-cells give rise to a concentric stratification of the bast. Möller states that in the sieve-tubes of *V. sebifera* the sieve-plates are not found on the end-walls of the segments, but on their longitudinal walls; it remains to be determined whether this is the case in all the members of this Order. Tannin is present in some abundance in the cortex.

Oxalate of lime is excreted chiefly in the form of small acicular crystals, and these occur in abundance in the cortex of the stem and in the veins of the leaf. In addition to these, clustered crystals are present in the leaf in many species, being mostly enclosed in rather large subepidermal cells.

The **hairy covering** of the Myristicaceae (Fig. 170) is of a very peculiar type, the hairs being generally described by systematists as of the stellate form; Warburg has recently made a careful examination of them. Although the various forms of hairs which occur in the individual species, or even on the different organs of the same plant, show considerable diversity when examined in detail, they may all be regarded as modifications of a single principal type. To express it shortly, the hairs of all the Myristicaceae are uniseriate trichomes sympodially branched. They may be classified in two categories, which are connected by transitional forms. The first of these (Fig. 170, *A–C*) is represented by hairs consisting of cells of the one-armed form; hairs of this type originate from a uniseriate trichome, through the component

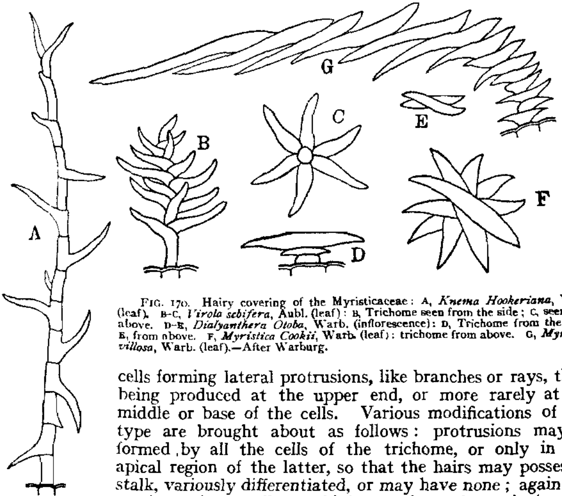

FIG. 170. Hairy covering of the Myristicaceae: A, *Knema Hookeriana*, Warb. (leaf). B–C, *Virola sebifera*, Aubl. (leaf): B, Trichome seen from the side; C, seen from above. D–E, *Dialyanthera Otoba*, Warb. (inflorescence): D, Trichome from the side; E, from above. F, *Myristica Cookii*, Warb. (leaf): trichome from above. G, *Myristica villosa*, Warb. (leaf).—After Warburg.

cells forming lateral protrusions, like branches or rays, these being produced at the upper end, or more rarely at the middle or base of the cells. Various modifications of this type are brought about as follows: protrusions may be formed by all the cells of the trichome, or only in the apical region of the latter, so that the hairs may possess a stalk, variously differentiated, or may have none; again the portions of the cells combining to form the main 'stem' of the trichome may be short or long; and lastly, the protrusions vary in length and show all transitions from papillose protuberances to ray-like processes, and the latter may radiate in the most varied directions. In this way a series of forms is obtained, from trichomes resembling stellate hairs to those of an abietiform type. The second category (Fig. 170, *D–G*) is composed of trichomes the cells of which are two-armed. In the simplest case we have a true, simple, two-armed hair, which is unicellular and is mostly seated on a low stalk-cell. More commonly one finds a pair of two-armed trichomes one above the other; in such hairs the two segments do not generally lie in one vertical plane, but intersect one another (Fig. 170, *D–E*). Further, it is not rare to find trichomes, which, apart from one or a few short basal cells, consist of a still larger number (as many as six) of two-armed cells, all intersecting at various angles in such a manner that the trichomes have the appearance of stellate hairs, when seen from above (Fig. 170, *F*). In other cases the number of two-armed cells is

much greater, and the trichomes appear like shaggy hairs to the naked eye; in these hairs the two-armed cells all lie in the same vertical plane (Fig. 170, *G*[1]). It may be added that Warburg also met with simple, unicellular hairs as an exceptional occurrence. Glandular hairs appear to be absent[2].

Literature: Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 69 and 365.—Möller, Rindenanat., 1882, pp. 223–5.—Blenk, Durchs. P., Flora 1884, p. 372 and sep. copy, pp. 84–5.—Solereder, Holzstr., 1885, pp. 225–6.—[Thouvenin, Local. du tannin dans les M. and Struct. des M., Bull. Soc. sc. Nancy 1887.]—Prantl, in Natürl. Pflanzenfam., iii. Teil, Abt. 2, p. 40.—Warburg, Haarbild. d. M., Ber. deutsch. bot. Gesellsch. 1895, pp. (78)–(82) and Tab. xxix; in Natürl. Pflanzenfam., Nachtr. u. Reg. zu Teil ii–iv, 1897, p. 162; and Monogr. d. M., Nova Acta, Halle, 1897.

MONIMIACEAE.

1. Review of the Anatomical Features. The following characters are those of most value for the anatomical diagnosis of the Order: the presence of secretory cells, which frequently give rise to transparent dots in the leaf; the absence of mucilage-cells and glandular hairs; the occurrence in the vessels of scalariform perforations, in addition to which simple perforations may also be present; the development of a composite and continuous sclerenchymatous ring in the pericycle, including stone-cells thickened in the shape of a horse-shoe (exceptions: *Conuleum* and many species of *Siparuna*); the excretion of oxalate of lime in the form of small acicular crystals, or small cubical or rhombohedral crystals, several of which invariably occur together in the same cell. With reference to the leaf-structure, it may be added that the leaves are bifacial, that hypoderm is developed beneath the upper epidermis in most species, and that the vascular bundles of the veins are usually surrounded by a sclerenchymatous ring. The type of stoma is not uniform, the guard-cells being either surrounded by several epidermal cells, or accompanied by subsidiary cells, which lie parallel to the pore. The prosenchyma which forms the groundwork of the wood bears either bordered or simple pits; septate prosenchyma bearing simple pits has been observed in all the species investigated. The medullary rays are strikingly broad in the Monimieae, but narrow in the Atherospermeae. The formation of cork takes place superficially. The hairy covering consists of simple unicellular trichomes, two-armed unicellular hairs (*Mollinedia, Matthaea, Atherosperma*), tufted hairs (*Peumus, Siparuna*), stellate hairs (*Monimia, Palmeria, Hortonia*, species of *Siparuna*, Fig. 171), and peltate hairs (*Conuleum*, species of *Monimia* and *Siparuna*). The following special features, found in certain species of *Siparuna*, may also be mentioned: the presence of tannin-sacs with wide lumina in the pith and bast; the occurrence of sclerenchymatous fibres in the mesophyll, and of an epidermis, two or more layers thick, in the leaf.

2. Structure of the Leaf. This has been investigated in detail by Hobein[3]. In all the species the leaf-structure is bifacial; the palisade-tissue mostly consists of a single layer, rarely of two or more layers of cells, which vary in length, whilst the spongy tissue is loose and frequently characterized by the presence of large intercellular spaces. The **epidermal cells** on both sides of the leaf are generally small, and usually have straight lateral walls, strongly undulated walls having only been observed in *Doryphora*. Gelatinization of the epidermis of the leaf does not occur, but the development of a **hypoderm**

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[1] See also tab. 40 et seq. in Flor. brasil. v, 1.

[2] I was unable to find the 'glandular papillae, consisting of a short stalk-cell and a second cell of only slightly greater size forming the head,' as mentioned by Warburg in *Myristica argentea*, Warb.

[3] The following genera were examined: (a) Tribe Monimieae: *Monimia, Tambourissa, Palmeria, Mollinedia, Kibara, Matthaea, Hedycarya, Peumus, Hortonia*; (b) Tribe Atherospermeae: *Conuleum, Siparuna, Atherosperma, Doryphora, Laurelia, Daphnandra.*

on the upper side of the leaf is a phenomenon of wide occurrence; among the genera and species examined by Hobein hypoderm is absent in the following cases only: *Atherosperma, Daphnandra, Matthaea* and certain species of *Siparuna*; according to Poisson, it is present in *Hennecartia.* The hypoderm consists either of a single layer (e.g. in *Mollinedia*) or of several (e.g. in *Monimia ovalifolia*, P. Th.). Its cells are usually larger than the epidermal cells in surface-view and frequently (*Monimia, Palmeria, Mollinedia, Tambourissa*) also exceed the latter in height in the transverse section. In some cases the walls of the hypodermal cells are thin (e.g. in *Hedycarya*), but often they are strongly thickened and pitted, and in *Monimia ovalifolia* they are lignified as well. In those species of *Siparuna* which have no hypoderm, the epidermis on the upper side of the leaf is simple (*S. chiridota*, A. DC., &c.), or consists of two or more layers, either throughout or only at certain points (in the majority of the species of *Siparuna*); in the latter case the appearance of horizontal division-walls in the epidermal cells is often confined to the neighbourhood of the trichomes. On the lower side of the leaf hypoderm has only been met with in *Laurelia sempervirens*, Tul. The **stomata** are almost exclusively confined to the lower side of the leaf; only in species of *Siparuna* have they been observed on the upper side, where they are restricted to the neighbourhood of the veins. The guard-cells are in most cases surrounded by several ordinary epidermal cells; Hobein states that in *Mollinedia, Kibara, Matthaea* and *Hedycarya* there are four subsidiary cells, two of which are placed laterally with reference to the guard-cells; he describes two lateral subsidiary cells in *Conuleum* also. The vascular systems of the larger **veins** are as a rule surrounded by a ring of hard bast. The only exception is found in a few species of *Siparuna*, in which the hard bast is absent or only slightly developed. In *S. mollicoma*, A. DC. and *S. mollis*, A. DC. sclerenchymatous fibres branch off from the sclerenchyma of the veins and run freely in the mesophyll, sometimes extending as far as the epidermis of the leaf.

Bokorny and Hobein met with **secretory cells** in the leaf in all the members of the Order investigated, and according to my own observations they are also present in the leaf of *Hennecartia.* The position in which they occur in the leaf is generally the mesophyll, and they frequently give rise to transparent dots in this tissue. Besides occurring in the mesophyll, however, they are also present in the epidermis of the leaf in certain species of *Tambourissa, Mollinedia, Conuleum* and *Siparuna*, and in *Daphnandra*, in the hypoderm in *Palmeria*; in *Monimia*, on the other hand, they are confined to the hypoderm and are only present in small numbers. In the axis the secretory cells are found in the pith, bast and primary cortex, and rarely (*Hedycarya arborea*, Forst.) in the medullary rays of the wood. The secretory elements are spherical in shape and their contents are for the most part clear, more rarely (species of *Siparuna*) coloured brown by tannin; their diameter varies from ·02 to ·06 mm. Mucilage-cells are not present in the Monimiaceae, this being a point of difference from the allied Laurineae.

Oxalate of lime is mostly present in the leaf and axis in the form of small acicular crystals, large numbers of which occur together in the same cell; they frequently occupy the whole of the mesophyll. In the genera belonging to the tribe Monimieae, besides the crystalline elements just referred to, there are small, cubical or rhombohedral crystals (attaining the greatest relative dimensions in *Mollinedia*), several occurring in the same cell; these crystals are found in the neighbourhood of the vascular bundles of the leaf and in the medullary rays of the axis. Ordinary large solitary and clustered crystals have not been observed in this Order.

The **hairy covering** consists of clothing hairs only. In most cases they are ordinary unicellular trichomes, usually with strongly thickened walls:

in *Kibara* the subsidiary cells of the hairs are also considerably thickened. The unicellular hairs of *Doryphora, Daphnandra* and *Laurelia* show a tendency to become tufted, two or three of them being frequently sunk in the epidermis side by side. *Mollinedia repanda,* R. et P. and *M. triflora,* Tul. exhibit transitions between ordinary unicellular trichomes and short two-armed unicellular hairs with thick or thin walls, such as occur in other species of *Mollinedia*, in *Matthaea* and *Atherosperma*. Large tufted hairs, often seated on prominent elevations of the leaf-surface, are found in *Peumus* and *Siparuna* ; their sclerenchymatous cells are concrescent at the base so as to produce a foot, which is often deeply sunk in the tissue of the leaf. Structures closely allied to the tufted hairs are the stellate hairs, in which the ray-cells are spread out in a plane parallel to the surface of the organ ; these hairs have been observed in certain species of *Siparuna*, in *Monimia, Palmeria* and *Hortonia*. Peltate hairs have been recorded in species of *Monimia, Siparuna* and *Conuleum*, and according to O. Bachmann and Hobein they are distinguished by the fact that their ray-cells have thin walls, are only partially concrescent, and do not meet at the centre of the shield, but along a median line (Fig. 171).

3. STRUCTURE OF THE AXIS. I have examined the structure of the **wood** in *Monimia ovalifolia*, P. Th., *Mollinedia Selloi*, A. DC., *Hedycarya arborea*. Forst., *Peumus Boldus*, Mol., *Atherosperma moschatum*, Labill., *Doryphora Sassafras*, Endl. and *Daphnandra micrantha*, Benth.; Hobein only dealt with the tissue of the medullary rays. According to him the medullary rays of the wood are broad in all Monimieae, being visible to the naked eye, or at any rate with a lens, while in the Atherospermeae they are narrow (from one to three cells in breadth). The diameter of the vessels is small (not exceeding ·036 mm.). The wall of one vessel in contact with that of another sometimes bears scalariform bordered pits, whilst in contact with parenchyma it generally has very large elliptical simple pits, with bordered pits as well. In *Peumus Boldus* a delicate spiral thickening of the wall is also present. The perforations of the vessels are generally exclusively scalariform, and often (e.g. in *Atherosperma*) have very numerous bars ; in *Monimia ovalifolia*, besides perforations with 1–12 bars, there are others which are simple and have an elongated elliptical outline ; *Peumus Boldus* has for the most part simple circular or elliptical perforations, those of the scalariform type occurring only in the neighbourhood of the primary wood. The prosenchymatous groundwork of the wood bears simple pits in *Monimia, Hedycarya, Peumus* and *Daphnandra*, small and often indistinct bordered pits in *Mollinedia*, and typical bordered pits in *Atherosperma* and *Doryphora* ; septate wood-fibres with simple pits have been observed in all species.

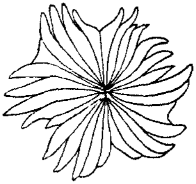

FIG. 171. Peltate hair of *Siparuna cristata*, A. DC.—After O. Bachmann.

According to Hobein, the most important character of the **cortex** is the composite and continuous sclerenchymatous ring in the pericycle. This ring is partly composed (perhaps in all cases, at any rate in the seven species in which I examined the structure of the wood) of hippocrepiform stone-cells, in which the outer tangential walls are not sclerosed. The sclerotic ring is wanting in *Conuleum* and in a large number of species of *Siparuna*, in which only isolated groups of bast-fibres are present. The development of cork takes place superficially, in a subepidermal position in *Siparuna limoniodora*, A. DC., and beneath the hypoderm in *Peumus Boldus*, Mol. and *Monimia ovalifolia*, P. Th. The primary cortex is not strongly developed, and consists, in most cases, of cells which have thin walls or are slightly collenchymatous ;

in *Laurelia* large intercellular spaces occur between the cells. The collenchyma is more strongly developed in species of *Siparuna*. In most of the genera (except *Matthaea*, *Peumus*, *Laurelia* and *Daphnandra*) sclerosis of the primary cortex sets in at an early stage, and in *Siparuna limoniodora*, A. DC. and *S. neglecta*, A. DC. this leads to the formation of a ring of stone-cells. According to Hobein, the secondary bast contains bast-fibres in *Conuleum*, and rod-cells in *Monimia*, *Hedycarya*, *Peumus* and *Conuleum*; Möller also mentions the occurrence of rod-cells in thick pieces of the cortex of *Atherosperma moschatum*, Labill. It remains to mention the presence of peculiar tannin-sacs, which correspond in every respect with the well-known sacs of *Sambucus nigra*; I have noticed these structures in *Siparuna limoniodora*, A. DC. and *S. guianensis*, Aubl. at the margin of the pith and in the bast.

Literature: Bokorny, Durchs. P., Flora *1882*, p. *366 et seq.* and sep. copy, pp. 23-5.—Möller, Rindenanat., 1882, pp. 99-103.—Solereder, Holzstr., 1885, pp. 226-7.—Poisson, *Hennecartia*, Paris, *1885*, *6 pp.* and 1 pl.—O. Bachmann, Schildh., Flora *1886*, sep. copy, p. *16* and Tab. viii.—Radlkofer, in Sitz.-Ber. Münch. Akad. 1886, p. 327.—Hobein, Anat. Charakt. d. M. etc., Engler, Bot. Jahrb., Bd. x, 1888, pp. 51-73.—Douliot, Périderme, Ann. sc. nat., sér. 7, t. x, 1889, p. 334.—Reiche, in Engler, Bot. Jahrb., Bd. xxi, 1895, p. 37 and Chilen. Holzgew., Pringsheim Jahrb., Bd. xxx, 1897, p. 88.—[Perkins, Beitr. z. K. d. M., Engler, Bot. Jahrb., Bd. xxv, 1898, Heft 4-5.]

LAURINEAE[1].

1. Review of the Anatomical Features. The Laurineae, like the allied Monimiaceae, are characterized by the constant presence of oil-cells. The mucilage-cells which occur in many genera of Laurineae, though not in all the species of these genera, constitute a very characteristic feature not found in the Monimiaceae. Other important characters are as follows: the subsidiary cells of the stomata are placed parallel to the pore of the guard-cells; the smaller veins of the leaf are vertically transcurrent; the medullary rays of the wood are narrow; there is a tendency to the formation of scalariform perforations, which, however, never have very numerous bars; in contact with parenchyma the walls of the vessels bear bordered or simple pits, often of large size; the wood-prosenchyma bears simple pits and is sometimes septate; bast-fibres may be rather abundant, or only present in small numbers in the secondary bast; there is a tendency to form a composite and continuous sclerenchymatous ring, including stone-cells with U-shaped thickenings; the development of cork is superficial; glandular hairs are absent, and simple, unicellular hairs are the only forms of trichome present; oxalate of lime is secreted solely in the form of small crystals, which are fusiform, acicular, or of other shapes. The parasitic genus *Cassytha* likewise has secretory cells, mucilage-cells and small acicular crystals, but is specially distinguished by possessing a xylem-ring devoid of medullary rays. The anatomical structure of the individual genera and species shows little diversity. The following special features have come under observation: development of hypoderm beneath the upper epidermis of the leaf (species of *Aydendron*, *Beilschmiedia*, *Cryptocarya* and *Ravensara*); sclerosis of isolated cells or groups of cells in the palisade-tissue (in species of *Ocotea*); transverse orientation of stomata on the stem of *Cassytha*.

2. Structure of the Leaf. A detailed investigation of the leaf-structure has not yet been made. In the few species which I have examined (*Laurus nobilis*, L., *Ocotea opifera*, Mart., *Litsea Neesiana*, Hemsley, *Persea gratissima*, Gaertn. f.) the leaf-structure is bifacial, and the **stomata** are only found on the lower surface. It is characteristic of the stomata that they are accompanied

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[1] We will follow the example of Pax by dealing with the genus *Hernandia* together with the genera *Gyrocarpus*, *Illigera* and *Sparattanthelium* (of the Gyrocarpeae) as a separate Order, Hernandiaceae, following the Laurineae.

by subsidiary cells—one on either side and parallel to the pore; the subsidiary cells are not easy to recognize (*Litsea Neesiana, Persea gratissima*) when both guard-cells and subsidiary cells are depressed. *Cassytha* also (*C. americana*, Nees) possesses stomata with subsidiary cells parallel to the pore; it is noteworthy, however, that the stomata both on the stem and on the rudimentary leaves lie transversely to the longitudinal axis of the organ. In many members of the Order the lower side of the leaf has a glaucous bluish bloom due to an excretion of wax. According to Pax, **hypoderm** is formed on the upper side of the leaf in *Cryptocarya, Aydendron, Ravensara* and in certain species of *Beilschmiedia*. According to Mez, some species of *Ocotea* (*O. grandifolia*, Mez, *O. opifera*, Mart., *O. Kunthiana*, Mez and *O. Rusbyana*, Mez) show the following special peculiarity: individual cells of the palisade-tissue or small groups of these cells are transformed into similarly elongated stone-cells. These sclerenchymatous elements are visible to the naked eye as distinct dots on the surface of the leaf. Mez further states that in other species of the same genus (*Ocotea alnifolia*, Mez, *O. Bofo*, H. B. K., *O. dispersa*, Mez and *O. punctulata*, Mez) the surface of the leaf bears fine black dots, a point which requires reinvestigation and explanation (cork-warts ?); I was unable to obtain material for this purpose. The **veins** of medium size are vertically transcurrent on both sides by means of more or less differentiated sclerenchymatous cells (both in the species mentioned above and in species of *Phoebe* and *Cinnamomum*, according to Perrot).

The **secretory elements** found in the Laurineae require a more detailed description. They are of two kinds, viz. (1) secretory cells with oily contents, and (2) mucilage-cells. Bokorny's investigations, supplemented by those of Hobein, have shown that oil-cells occur in the leaves of all the plants investigated (species of *Cryptocarya, Beilschmiedia, Dehaasia, Aydendron, Ajouea, Endiandra, Acrodiclidium, Cinnamomum, Machilus, Persea, Alseodaphne, Phoebe, Ocotea, Mespilodaphne, Dicypellium, Nectandra, Sassafras, Actinodaphne, Dodecadenia, Litsea, Lindera, Laurus*; and according to recent observations of my own in *Umbellularia* also). These secretory cells are moreover present in the parasitic genus *Cassytha* (*C. americana*, Nees), where Hackenberg and I observed them in the pith and leaf-tissue respectively. The secretory cells, like the mucilage-cells to be described below, frequently give rise to transparent dots in the leaf; they are found both in the palisade and spongy tissue, and in rare cases (*Umbellularia californica*, Nutt.) in the lower epidermis also. They are generally spherical in shape; those situated in the palisade form the only exceptions, since they appear as enlarged sac-like cells of this tissue. The walls of the secretory cells are suberized, and their contents are homogeneous and in most cases yellowish. In every case, by suitable treatment of the sections, the presence of the wall of the secretory cell can be demonstrated; the resin-lacunae, stated by Chatin to occur in the Laurineae, do not exist. In the epidermal secretory cells of *Umbellularia*, the whole of the outer wall does not reach the external surface, but only a circular portion, and at the centre of the latter there is a small dot-like area of thinner cell-wall. In the branch the secretory cells are found in the pith and cortex, and also in the medullary rays and the parenchyma of the wood. In the pith and primary cortex they are approximately isodiametric, while those in the bast are elongated in the vertical direction. The occurrence of these secretory cells in the wood of the root in *Sassafras* has long been known, and on this depends the medicinal use of this part of the plant. According to Höhnel, Felix and Knoblauch, however, the secretory cells are also present in the wood of the stem in many members of the Order[1]. Knoblauch met with them in

[1] Felix also met with them in fossil wood, belonging to members of the Laurineae.

the medullary rays or parenchyma of the wood in the stem of species of the genera *Cryptocarya, Beilschmiedia (Hufelandia), Aydendron, Acrodiclidium, Cinnamomum, Persea, Oreodaphne, Dicypellium, Nectandra, Sassafras, Litsea, Umbellularia* and *Laurus*. I may add that occasionally the secretory cells may even be observed in the medullary rays of the wood in branches from herbarium-material (e.g. in *Nectandra angustifolia*, Nees et Mart.). Secretory elements of the second kind, i.e. the mucilage-cells, are not so widely distributed as the oil-cells, for they only occur in certain species of certain genera. Bokorny met with them in the leaf in species of the genera *Beilschmiedia, Dehaasia, Aydendron, Machilus, Persea, Alseodaphne, Phoebe, Ocotea, Mespilodaphne, Nectandra, Sassafras, Actinodaphne, Litsea* and *Lindera*, whilst Radlkofer found them in *Acrodiclidium*; according to Hallier and my own observations, they also occur in the leaves of *Cassytha americana*. With the exception of this last species, in which the entire mesophyll abounds in mucilage-cells with wide lumina, these cells generally occur only in the palisade-tissue in the leaf. In the axis the mucilage-cells are invariably (?) present in the form of cells, elongated in the vertical direction; they occur chiefly in the bast (e.g. in cinnamon-barks, in *Litsea Neesiana*, Hemsley and *Persea gratissima*, Gaertn. f.), more rarely in the primary cortex also [1] (e.g. in *Cassytha americana*, Nees, where they were observed by Hackenberg, but incorrectly interpreted, and in *Persea gratissima*). The mucilage-cells in most cases show distinct stratification of the mucilage and a very small lumen; hence it may be concluded that the mucilage arises by metamorphosis of the cell-wall. Before leaving the subject of the secretory organs we may point out that Höhnel's statement as to the occurrence of resin-canals in the medullary rays of the wood in a species of *Oreodaphne* (Laurier de Montagne from Martinique) is without doubt incorrect; and the same is to be said of Plitt's statement regarding the occurrence of oil-canals in the petiole.

Oxalate of lime occurs chiefly in the form of small acicular or spindle-shaped crystals; crystals of somewhat larger size are rare, being found in the neighbourhood of the vascular bundles (e.g. in the cortex of the branch of *Endiandra virens*, F. v. Müll., in the cells of the sclerenchyma-ring, which exhibit U-shaped thickenings). The crystals first mentioned occur both in the leaf and axis, several being invariably found in the same cell. Clustered and ordinary large solitary crystals are entirely absent. Perrot, it is true, mentions the occurrence of clustered crystals in the primary cortex of *Nectandra angustifolia*; his material, however, as shown by reinvestigation of the same species, was incorrectly determined, and does not belong to any member of the Laurineae.

The **hairy covering** is very uniform. Glandular hairs are not present, nor are there any special forms of trichomes. All the hairs found in the Laurineae are simple and unicellular, and are often sclerenchymatous.

According to Plitt's investigations the fibro-vascular system of the **petiole** consists of an arc of vascular bundles (in species of *Cinnamomum, Cryptocarya, Laurus, Persea* and *Tetranthera*).

3. Structure of the Axis. The Laurineae on the whole also show uniform features in the structure of the axis. The genus *Cassytha* alone constitutes an exception, and may therefore be described separately in the following paragraph.

In *Cassytha americana*, Nees the pith consists of lignified, but thin-walled cells; it is surrounded by a xylem-ring, which shows two characteristic features: firstly,

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[1] Höhnel also observed spindle-shaped mucilage-cells in a wood, used in Southern China for the preparation of an adhesive gum under the name of Pan-Fa, and said to belong to the Laurineae; the mucilage-cells in this case are found either singly or in groups.

the absence of medullary rays, and, secondly, the presence of slight ridges alternating with furrows at the periphery of the xylem, the bundles of soft bast of the vascular ring being inserted in the furrows. The inner portion of the xylem-ring, with the exception of the small primary groups of tracheae, consists of vessels with very wide lumina (diameter = ·12 mm. or more) and of wood-parenchyma, whilst the peripheral portion is dense, and is composed of vessels with very small lumina, wood-prosenchyma and wood-parenchyma. The vessels of *Cassytha* have simple perforations throughout; their walls are provided with very large, circular, bordered pits. The wood-prosenchyma bears simple pits. In the pericycle one finds isolated groups of bast-fibres with white walls. Externally this is followed by the primary cortex containing chlorophyll [1], mucilage-cells and abundant small acicular crystals, and bounded by the epidermis, which has transversely placed stomata, already described above [2].

The features of the axis common to the other members of the Order have been summarized above in the general review of the anatomical characters.

The structure of the **wood** has been examined chiefly by Knoblauch, who had abundant material [3].

The vessels have lumina of medium size (maximum diameter = ·03–·075 mm.), usually fairly constant throughout the same annual ring. *Sassafras* alone is distinguished by the fact that the vessels of the spring-wood have very wide lumina, while those of the autumn-wood have narrow lumina. In most of the species the perforations of the vessels are both simple and scalariform. Scalariform perforations occurring alone were observed by Knoblauch in *Hufelandia pendula*, Nees, but in no other cases. The scalariform perforations mostly have few bars, the largest number observed being seventeen (in *Cryptocarya Wightiana*, Thw.). Knoblauch also mentions a number of cases in which he observed simple perforations only (species of *Beilschmiedia*, *Acrodiclidium*, *Oreodaphne* pro parte, *Dicypellium*, *Nectandra*, *Actinodaphne*, *Litsea* pro parte, *Umbellularia*, *Laurus* pro parte). Further investigation is necessary to determine whether scalariform perforations do not really occur in these species in the neighbourhood of the primary wood, as is to be expected from analogy (e.g. with *Endiandra virens*, F. v. Müll., which I investigated). The structure of the wall of the vessel in contact with parenchyma of the medullary rays is very characteristic. It shows bordered pits with transitions to simple pits; the simple pits are sometimes large and elliptically elongated, a group of them reminding one of a scalariform perforation. Spiral striation of the walls of the vessels is mentioned by J. Möller as occurring in species of *Tetranthera* and *Camphora*. The medullary rays of the wood are mostly 1–3, rarely as much as five cells in breadth, and the ray-cells vary in height. The wood-parenchyma may be little developed or fairly abundant. Tangential bands of wood-parenchyma are stated by Knoblauch to occur in *Beilschmiedia Roxburghiana*, Nees, *Actinodaphne elegans*, Thw. and *Litsea dealbata*, Nees, and by Reiche in *Cryptocarya Peumus*, Nees. The wood-prosenchyma has walls of varying thickness; in the young parts of the wood the gelatinous layer is occasionally differentiated (e.g. in *Persea indica*, Spreng. or *Oreodaphne bullata*, Nees). The pits of the wood-prosenchyma are simple; the lumina are septate by means of delicate transverse walls in species of *Beilschmiedia*, *Ayden-*

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[1] Thus *Cassytha* is not devoid of chlorophyll, as stated in many works (Kerner, Pflanzenleben, i, p. 158, &c.). For details see Hackenberg, loc. cit.

[2] Anatomical investigation affords an easy means of distinguishing *Cassytha* from *Cuscuta*, which is similar in habit; in *Cassytha* alone a pith is present, and a mass of wood showing a slightly stellate transverse section.

[3] Knoblauch investigated the wood in the stem of thirty-three species of the following genera: *Cryptocarya*, *Beilschmiedia* (incl. *Hufelandia*), *Aydendron*, *Acrodiclidium*, *Cinnamomum*, *Machilus*, *Persea*, *Oreodaphne*, *Dicypellium*, *Nectandra*, *Sassafras*, *Actinodaphne*, *Litsea*, *Tetranthera*, *Umbellularia*, *Lindera* and *Laurus*.

dron, Acrodiclidium, Cinnamomum, Machilus, Persea, Oreodaphne, Dicypellium, Nectandra, Sassafras, Litsea and *Umbellularia*.

The structure of the **pith** has been examined in detail only in the case of *Cinnamomum zeylanicum* by Mentovich. The pith in this plant is heterogeneous. It is differentiated into a peripheral portion, composed of small active cells with thick walls, and a central portion consisting of empty cells with thin walls.

The development of **cork** takes place at a relatively late stage. The cork arises superficially, either in the epidermis, which usually has a thick outer wall (*Laurus nobilis*, L. and *Cinnamomum dulce*, Nees, according to Möller), or in the outermost cell-layer of the primary cortex (*Tetranthera japonica*, Spreng., according to J. E. Weiss). According to Möller, the cells of the cork either have thin walls (species of *Persea, Litsea, Sassafras*), or the inner tangential walls are sclerosed (species of *Cinnamomum, Dicypellium, Oreodaphne, Tetranthera*). In *Tetranthera japonica*, according to Weiss, sclerosed cork-cells with strongly thickened outer walls alternate with thin-walled cells, which are elongated in the radial direction and apparently not suberized. Stone-cells sometimes appear in the **primary cortex** of older branches. The structure of the pericycle is very characteristic. The isolated groups of primary bast-fibres are united to form a closed or only locally interrupted sclerenchymatous ring by means of stone-cells; some of the latter have thin outer tangential walls, but sclerosed inner tangential and radial walls, so that they exhibit U-shaped thickenings in transverse sections of the branch. A pericyclic ring of this kind has been observed by Möller in species of *Cryptocarya, Beilschmiedia, Endlicheria, Acrodiclidium, Cinnamomum, Persea, Phoebe, Ocotea, Agathophyllum, Dicypellium, Nectandra, Sassafras, Litsea, Lindera* and *Laurus*; also by Perrot in *Daphnidium*, and by me in *Nectandra angustifolia*, Nees et Mart. (contrary to the statement made by Perrot, whose material certainly did not belong to any member of the Laurineae) and *Endiandra virens*, F. v. Müll. The secondary **bast** in most cases contains spindle-shaped fibres of rounded quadrangular section, and having narrow lumina; these fibres rarely (*Acrodiclidium, Beilschmiedia, Ocotea*) appear in large numbers, forming bundles; usually there are only few present. Stone-cells sometimes accompany the fibres, some of them being thickened on one side only, like those of the pericycle; the stone cells are developed in exceptional abundance in the older cortex of certain species (species of *Cryptocarya* and *Tetranthera*).

Literature: Chatin, Anat. comp. des végétaux, pl. iv–v and Gland. fol., Ann. sc. nat., sér. 6, t. ii, 1875, pp. 214–16 and pl. 15.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 36–9 and 332 et seq.—Zacharias, in Bot. Zeit. 1879, p. 626.—Höhnel, Sekretionsorg., Sitz.-Ber. Wiener Akad., Bd. lxxxiv, Abt. 1, 1881, p. 596.—Bokorny, Durchs. P., Flora 1882, p. 359 et seq. and sep. copy, pp. 16–22.—Höhnel, Gefässf. Hölzer mit Harzg., Bot. Zeit. 1882, pp. 165–6.—Möller, Rindenanat., 1882, pp. 103–13.—Felix, Fossile Hölzer, Zeitschr. deutsch. geol. Gesellsch., Bd. xxxv, 1883, p. 62 and Holzopale, Mitt. Jahrb. ung. geol. Anst., Bd. vii, 1883, pp. 27–8.—Mentovich, Mark, Klausenburg, 1885; abstr. in Just 1885, i, p. 787.—Solereder, Holzstr., 1885, p. 227.—Plitt, Blattstiel, Diss., Marburg, 1886, pp. 35–6.—Radlkofer, Durchs. P., Sitz.-Ber. Münch. Akad. 1886, p. 327.—Knoblauch, Anat. d. Holzes d. L., Flora 1888, pp. 339–400 and Tab. vii.—Hobein, Anat. Charakt. d. L., Engler, Bot. Jahrb., Bd. x, 1889, p. 74.—Hackenberg, *Cassytha americana*, Verh. naturhist. Ver. d. preuss. Rheinlande etc. 1889, pp. 98–138.—Mez, L. americ., Jahrb. Berliner Gart., Bd. v, 1889, sep. copy, pp. 499–500.—Lalanne, Feuilles persist., Act. Soc. Linn. de Bordeaux, sér. 5, t. iv, 1890, p. 66 and pl. iv.—J. E. Weiss, Korkbild., Denkschr. Regensb. bot. Gesellsch. 1890, sep. copy, p. 55.—Pax, in Natürl. Pflanzenfam., iii. Teil, Abt. 2, 1891, pp. 106–7.—Perrot, Ét. hist. des L., Thèse, Lons-le-Saunier, 1891, 62 pp.—H. Hallier, Glied. d. Convolv., Engler, Bot. Jahrb., Bd. xvi, 1893, p. 540.—Reiche, Chilen. Holzpfl., Pringsheim Jahrb., Bd. xxx, 1897, p. 86 et seq.—J. Möller, Lignum Aloës, Pharmaceut. Post 1897.—(With regard to the cinnamon-barks see the pharmacognostic works of Berg, Vogl, Tschirch, &c.

HERNANDIACEAE.

According to Pax, this Order is composed of the three genera *Gyrocarpus*, *Sparattanthelium* and *Illigera* (of the Gyrocarpeae), and the genus *Hernandia*[1]. While the mode of dehiscence of the anthers and other exomorphic features show the close connexion between this Order and the Laurineae, this is also indicated by the anatomical characters. The most important of these are the possession of secretory cells and the excretion of oxalate of lime in the form of small, acicular crystals. In these two anatomical characters, and also in the absence of intraxylary soft bast, the genera of Gyrocarpeae differ widely from the Combretaceae, with which they are associated by Bentham and Hooker, and others. The cystoliths of *Gyrocarpus* and *Sparattanthelium* constitute a special anatomical feature, though not found in all members of the Order[2].

The leaves of the Hernandiaceae have bifacial structure, the palisade-tissue most usually consisting of a single layer. The **stomata** are found only on the lower side of the leaf. In *Gyrocarpus* and *Sparattanthelium* they are surrounded by a number of ordinary epidermal cells, while in *Illigera* (excluding *I. obtusa*, Meissn.[3]) and *Hernandia* they are accompanied by subsidiary cells, arranged parallel to the pore. **Hypoderm**, consisting of from one to two layers, has been observed on the upper side of the leaf in *Gyrocarpus acuminatus*, Meissn., *G. asiaticus*, Willd. var. γ, *G. rugosus*, R. Br., and *Illigera appendiculata*, Bl.; other species of *Gyrocarpus* and *Illigera*, and also species of *Sparattanthelium* show division by means of horizontal walls in certain cells of the upper epidermis of the leaf. In the anomalous species *Illigera obtusa* the lower epidermal cells of the leaf are produced into coronate papillae, which are connected with one another by ridges of cellulose. The vascular bundles of the **veins** are accompanied by sclerenchyma in the investigated species of *Sparattanthelium*, *Illigera* and *Hernandia*.

The **hairy covering** usually consists only of clothing hairs. The latter in *Gyrocarpus*, *Sparattanthelium* and *Illigera* are ordinary unicellular sclerenchymatous trichomes, accompanied by unicellular bracket-hairs in certain species of the three genera. In *Hernandia sonora*, rather short, unicellular hairs with wide lumina are present in the floral region; the anomalous species *Illigera obtusa* has ordinary unicellular trichomes with transitions to typically two-armed hairs, the arms being of equal length. The glandular hairs of *Illigera* (excl. *I. obtusa*) consist of a short unicellular stalk and a two-celled head, shaped like the teleutospore of a *Puccinia* (Fig. 172, *A*).

Oxalate of lime, both in the axis and leaf, is almost exclusively excreted in the form of small, acicular crystals (except in *Illigera obtusa*, where ordinary large solitary crystals occur in the neighbourhood of the vascular bundles). In the leaf the acicular crystals are found both in the vascular bundles and mesophyll, and also in the upper and lower epidermis, where they are abundant and are accompanied by quite small octohedral solitary crystals; they sometimes occur even in the guard-cells, and in *Illigera* also in the heads of the glandular hairs. By the presence of **cystoliths** the two closely related genera *Gyrocarpus* and *Sparattanthelium* are distinguished from the other members of the Order. The cystoliths of the leaf are generally confined to the integumental tissue; they are rarely found also in the soft bast of the veins (*Sparattanthelium amazonum*, Mart.), or in the tissue surrounding the

[1] See footnotes on pp. 343 and 702.

[2] Most important literature: Solereder, 1889; in addition to the species of Gyrocarpeae, mentioned there, the structure of the axis and leaf was also investigated in *Hernandia sonora*, L.

[3] *Illigera obtusa*, Meissn. differs from the other species of *Illigera* not only in this respect but also in the nature of the fruit and in other anatomical characters (see below), and should at any rate be excluded from the genus *Illigera* (cf. Flora Brit. Ind. ii, 1879, p. 461).

vascular bundles (*Gyrocarpus asiaticus*, Willd.), or even in the mesophyll (*G. rugosus*, R. Br.). The integumental cystoliths occur in the hypoderm in those species in which a hypoderm is present; in other cases they lie in epidermal cells the shape of which is adapted to that of the cystoliths; in the latter case only a small portion of the epidermal cell reaches the surface of the leaf, but it is to this part of the wall that the stalk of the cystolith is attached. The form of the cystolith differs in the two genera. *Gyrocarpus* has spherical or ellipsoidal cystoliths, whilst those of *Sparattanthelium* (Fig. 172, *B*) are branched, and usually have six arms, radiating from a common centre, their arrangement coinciding with three intersecting axes. The cystoliths may or may not be calcified; their skeleton gives the cellulose-reaction. The calcified cystoliths are generally visible even with the naked eye as granular dots (*Gyrocarpus*), or small striae or stars (*Sparattanthelium*) on the surface of the leaf. The cystoliths may also occur in the axis, e.g. in the primary cortex of *G. asiaticus*.

Secretory cells with oily contents are present in all the members of the Order, and in *Hernandia*[1] mucilage-cells occur as well. The secretory cells sometimes give rise to transparent dots in the leaf; they are found in the epidermis of the leaf (only in certain species of *Sparattanthelium*, *Illigera* and *Hernandia*), in the palisade (only in *Illigera* and *Hernandia*), or spongy tissues, and in the ground-tissue of the veins; in the axis the secretory cells are found in the pith, bast and primary cortex. The secretory cells of the leaf are spherical, with the exception of those occurring in the palisade-tissue, which have the form of enlarged cells of this tissue.

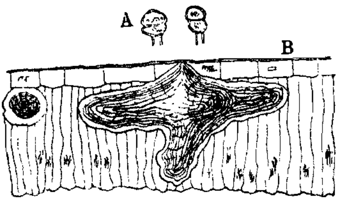

FIG. 172. A, Glandular hairs of *Illigera Coryzadenia*, Meissn. B, Transverse section through the upper portion of the lamina of the leaf of *Sparattanthelium Botocudorum*, Mart.—Original.

The structure of the **axis** has been examined in *Gyrocarpus asiaticus*, Willd., *Sparattanthelium Tupinambazum*, Martius, *Illigera Khasiana*, Clarke, and *Hernandia sonora*, L. The formation of cork takes place superficially, viz. in the outermost cell-layer of the primary **cortex** in *Hernandia sonora*, and in the second layer of the cortex in *Gyrocarpus asiaticus*. In the two species mentioned the cork consists of cells with wide lumina and thin walls. The outer portion of the primary cortex is composed of collenchymatous tissue; in *Sparattanthelium Tupinambazum* the inner portion consists of parenchymatous cells with wide lumina and lignified walls. In the four species mentioned above the pericycle contains strongly developed bundles of various types of sclerenchymatous fibres; only in *Gyrocarpus* are these fibres united to form a continuous sclerenchymatous ring by means of stone-cells with U-shaped thickenings, as in the Laurineae. The bast requires no special mention. The **wood** is soft, and consists of (*a*) vessels with fairly wide lumina, (*b*) narrow medullary rays, and (*c*) wood-prosenchyma with relatively wide lumina, walls of no great thickness, and simple pits. Where the vessels abut on one another they have relatively large bordered pits, and in contact with parenchyma they bear transitions from bordered pits to large simple pits. The perforations of the vessels are for the most part exclusively simple; in *Hernandia* some of them are scalariform, but with few bars.

[1] This statement is founded on an investigation of *H. sonora*; Bokorny only mentions resin-cells as occurring in *Hernandia*.

Literature: Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 41 and 337.—Bokorny, Durchs. P., Flora 1882, p. 359 et seq. and sep. copy, p. 16 et seq.—Solereder, Anat. u. Syst. d. Combret., Bot. Centralbl. 1885, iii, p. 161 et seq., Holzstr., 1885, pp. 121–9 and 227 and Blattspr. bei den Gyrocarp., Engler, Bot. Jahrb., Bd. x, 1889, pp. 511–20 and Tab. xiv.—Kohl, Kalks. etc., 1889, p. 134.—Pax, in Natürl. Pflanzenfam., iii. Teil, Abt. 2, 1889, pp. 126–9.

GOMORTEGACEAE.

Gomortega nitida, Ruiz et Pav., which is the only representative of this Order, agrees with the Laurineae and Monimiaceae in possessing secretory cells, and in the presence of a composite sclerenchymatous ring including stone-cells with horseshoe-like thickenings in the pericycle.

The leathery **leaf** is typically bifacial, the palisade-tissue consisting of several layers, while the spongy tissue is lacunar. The epidermal cells on both sides of the leaf have straight lateral walls. Beneath the upper epidermis of the leaf a thick-walled hypoderm is developed, consisting of from one to two layers, the cells of which are polygonal in surface-view and considerably larger than the epidermal cells. The stomata are found only on the lower side of the leaf, and are accompanied on either side by a single subsidiary cell placed parallel to the pore; a secondary division occasionally takes place in the subsidiary cells in a direction at right angles to the pore. The vascular bundles of the veins are provided with a strongly developed sheath of sclerenchyma.

The following statements may be made regarding the **structure of the stem**. The xylem consists of (*a*) wood-prosenchyma with bordered pits; (*b*) narrow medullary rays, the cells of which are somewhat elongated in the vertical and radial directions; (*c*) vessels with small lumina (maximum diameter = ·03 mm.), exclusively scalariform perforations (mostly having numerous bars), and walls bearing relatively large simple pits in contact with parenchyma of the medullary rays; and (*d*) a small amount of wood-parenchyma. The pericycle contains a composite and fairly continuous ring of sclerenchyma, composed of groups of bast-fibres, and of stone-cells sclerosed on all sides or on one side only. According to Reiche, 'sclerenchymatous cells resembling idioblasts' occur in the older portions of the secondary bast.

The **secretory cells** are filled with a yellow resinous secretion; their shape is approximately spherical in the pith and primary cortex, and in the palisade and spongy tissues and the hypoderm of the leaf, while those in the soft bast are elongated in the vertical direction. **Oxalate of lime** is only present in small quantities, and occurs in the medullary rays of the bast, and in the neighbourhood of the veins of the leaf, in the form of small acicular or prismatic crystals, a number of them being found in the same cell. Trichomes are absent.

Literature: Reiche, *Gomortega*, Ber. deutsch. bot. Gesellsch. 1896, p. 229.—Harms, in Natürl. Pflanzenfam., Nachtr. u. Reg. zu Teil ii–iv, 1897, p. 173.

PROTEACEAE.

1. Review of the Anatomical Features. Existing investigations point to the following anatomical characters as common to the Proteaceae: (*a*) in the structure of the branch, the simple perforations of the vessels; the bordered pits on the thick walls of the wood-prosenchyma; the superficial development of cork; and the occurrence of secondary hard bast; (*b*) in the structure of the leaf, the nature of the stomatal apparatus, the guard-cells being accompanied by subsidiary cells placed parallel to the pore. In most cases the wood in transverse section shows vessels with relatively small lumina and arranged tangentially; the vessels are embedded in tangential bands of wood-paren-

chyma, and the medullary rays are broad. Internal secretory receptacles, viz. secretory cavities with red or reddish-brown contents, have only been observed in the genera *Adenanthos* and *Franklandia*; in *Franklandia* (Fig. 173, *C*) the secretory space is traversed in a remarkable manner by a network of narrow cells, which are inserted on the papillose epithelial cells. Gelatinization of the epidermis of the leaf has not been observed in any species. Oxalate of lime is present in the form of clustered and solitary crystals. The hairy covering (Fig. 173, *E–F*) consists of simple trichomes composed of one or a few cells; in the genera *Grevillea* and *Hakea* bicellular two-armed hairs occur; short hairs with a terminal cell shaped like an ascus (glandular hairs ?) have been observed in *Lambertia*. An investigation of the leaf presents a large number of special anatomical features, viz. the bifacial or centric structure of the leaf; the numerous details connected with the differentiation of the middle layer (see Fig. 173); the occurrence of mechanical cells of various shapes in the mesophyll in numerous members of the Order; the vertical transcurrence of the veins in some cases by means of sclerenchyma; the development of hypodermal tissue (*Banksia*, *Dryandra*, *Franklandia*); the varied position of the stomata, which either lie on a level with the epidermis or are depressed; the occurrence of stomata in small pits on the leaf-surface (*Banksia*, *Dryandra*).

2. STRUCTURE OF THE LEAF. In the leaves, which are mostly leathery and narrow, the anatomical structure is the expression of an adaptation to the dry season, which the plants have to withstand, more particularly those growing in the subtropical regions of South Africa and New Holland. The mesophyll of the leaves has been especially examined by Bengt Jönsson, while Mohl, Strasburger, Tschirch and others have investigated the peculiar position of the stomata in many species.

The **leaf-structure** is either bifacial or centric (Fig. 173, *A–C*). In the latter case, which is quite general where the leaf is very narrow or acicular, an envelope of one or more layers of palisade-cells surrounds a medullary tissue with little or no chlorophyll; in some cases the medullary tissue probably serves for water-storage, whilst in others (*Franklandia fucifolia*, R. Br.) it has thick walls, and stores up starch. Mechanical cells frequently occur as special elements belonging to the mesophyll; according to Jönsson there are essentially three forms of these elements. The first are prop-cells, viz. sclerenchymatous elements, elongated like palisade, belonging to the palisade-parenchyma and having short, root-like branches at both ends (species of *Adenanthos*, *Grevillea*, *Hakea*, *Isopogon*, *Molloya*, *Petrophila*, *Roupala* and *Stenocarpus*). In the medullary tissue of the leaves of some species of *Isopogon* (*I. petrophiloides*, R. Br., *I. cornigerus*, Lindl. and *I. spathulatus*, R. Br.) these mechanical elements are replaced by stellately branched sclerenchyma-cells with thin rays resembling the arms of an Ophiurid (Fig. 173, *B*). In a third group of species, only ordinary sclerenchyma-cells are present (species of *Adenanthos*, *Bellendena*, *Hakea Isopogon*, *Leucospermum*, *Nivenia*, *Sorocephalus* and *Xylomelum*); they are usually unbranched, or in other cases more or less branched. In the acicular leaves of *Isopogon adenanthoides*, Meissn. the whole of the medullary tissue is converted into sclerenchyma, with the exception of a narrow peripheral zone containing solitary crystals; finally, in the bifacial leaf of *Grevillea Hilliana*, F. v. Müll. the sclerenchymatous fibres accompanying the vascular bundles branch off from the latter and traverse the palisade-tissue in a direction at right angles to the surface of the leaf, ultimately spreading out in considerable numbers between the palisade-tissue and the upper epidermis. The **vascular bundles** of the leaf are always accompanied by sclerenchyma, but the latter varies in amount. Sometimes, even in the smaller veins of flat leaves, it forms vertically transcurrent plates reaching as far as the epidermis on either side

(species of *Banksia, Synaphea* and *Dryandra*). In flat leaves the arrangement of the vascular bundles follows the normal type; in very narrow or acicular leaves having a considerable number of bundles there is either one larger bundle at the centre of the medullary tissue, while the remainder are situated near the periphery of this tissue, or both large and small bundles are scattered irregularly in it, or all of them lie at the periphery. In *Hakea sulcata*, R. Br. the larger vascular bundles of the leaf, which are arranged in a ring at the margin of the pith, resemble the bundles in the flat leaves of certain species of the genera *Banksia*,, &c., in having strongly developed masses of sclerenchyma opposite and external to their xylem-groups; these traverse the palisade-tissue and reach as far as the epidermis.

There is little to be said regarding special contents in the mesophyll. Crystals of **oxalate of lime** appear to be, on the whole, of rather rare occurrence. Among the different species figured by Jönssen, he only shows solitary crystals in the peripheral part of the medulla of the leaf of *Isopogon adenanthoides*, and in the epidermis of the leaf in *Hakea marginata*; De Bary mentions the occurrence of solitary crystals in the epidermis of the leaf of *Hakea saligna*; in a casual examination of *Adenanthos obovata*, Labill. and *Franklandia fucifolia*, R. Br. I found, in the medullary tissue of the leaf, abundant clustered crystals of varied structure, as well as comparatively small numbers of solitary crystals. Möller states that, in investigating the ' bark ' of species belonging to the genera *Banksia, Hakea, Leucadendron* and *Leucospermum*, he observed clustered crystals in the primary cortex in *Banksia* and *Leucadendron* only; in all other cases (even in the bast) he found no crystals.

Another point of special interest is Jönsson's statement on the occurrence of ' glandel ' in the leaf of *Franklandia fucifolia* and some species of *Adenanthos* (*A. apiculata*, R. Br., *A. barbigera*, Lindl., *A. obovata*, Labill., *A. sericea*, Labill.). I have investigated *Franklandia fucifolia*, R. Br. and *Adenanthos obovata*, Labill. with reference to this point, and I am able to state that these glands are **secretory cavities**, lined by a delicate one-layered epithelium, and filled with brown contents. The secretory cavities of *Adenanthos obovata* are fairly large spherical spaces in the palisade-tissue. Those of *Franklandia fucifolia* (Fig. 173, *C*) are far larger, and are even visible to the naked eye as pustules on the peculiar, dichotomously divided leaves, which look more like branches; a transverse section shows that the secretory cavities not only traverse the palisade-parenchyma, but also penetrate deeply into the medulla of the centric leaf. Closer examination of the secretory cavities of *Franklandia* shows that the secretory space, which is filled with reddish-brown, crystalline, doubly refractive contents, is traversed by a network of narrow, elongated, thin-walled cells, connected with papillose protrusions of the epithelium. These extremely peculiar secretory cavities of *Franklandia* may be recommended for developmental investigation in fresh material. In some respects they are probably comparable to the well-known intramural glands of *Psoralea*, and the secretory cavities discovered by Köpff in certain species of *Lonchocarpus*. A third feature connected with the presence of special contents in the mesophyll is the occurrence of a sheath of cells surrounding the medulla and the vascular system in the centric leaf of *Aulax umbellata*, R. Br.; the cells of this sheath are elongated parallel to the surface of the leaf, and are filled with brown contents.

In describing the integumental tissue the subjects deserving more thorough treatment are: the development of hypoderm, the stomata, and the trichomes. There are, however, other features worth mentioning, and we will take these first. Gelatinization of the **epidermis** of the leaf, contrary to what one would expect, has not been observed in any member of the Order; silicification of the walls of the epidermal cells occasionally takes place (species of *Hakea*). The outer wall of the epidermal cells is considerably thickened in most cases in this

Order, and so is the cuticle. In some Proteaceae, at the line of junction of the cuticle and the cellulose portion of the outer wall, there are, according to Nägeli and De Bary, blunt cuticular processes with intervening slits into which the cellulose portion of the wall penetrates; in a surface-view of the cell, these slits appear as striae with irregular radial arrangement around a central point, or in elongated cells arranged about two excentric points; sometimes also they branch and anastomose. Tschirch mentions the occurrence of a waxy covering on the surface of the leaf in *Protea mellifera*. In *Embothrium coccineum*, Forst. the epidermal cells are provided with papillae, in the formation of which the external wall is principally concerned. The **hypoderm** consists of one or more layers; according to Jönsson's drawings the cells of this tissue are generally not much larger than those of the epidermis, and in *Dryandra floribunda*, R. Br. they resemble fibres. Hypoderm is present in the bifacial leaves of numerous species of *Banksia* and *Dryandra*, as well as in the centric leaf of *Franklandia fucifolia*, R. Br. (Fig. 173, *C*). With regard to the **stomata**, the most important feature, at any rate for systematic purposes, is that the pair of guard-cells, in the cases more carefully examined by Mohl, Strasburger and De Bary (species of *Grevillea, Hakea, Leucadendron, Mimetes, Persoonia* and *Protea*, and also in *Adenanthos obovata*, Labill. and *Lambertia multiflora*, Lindl., as I learnt from a casual observation), are accompanied on either side by one or two subsidiary cells, arranged parallel to the pore; these subsidiary cells are cut off secondarily from the cells adjacent to the guard-cells or from the mother-cell of the stoma, as Strasburger has shown in species of *Grevillea* and *Hakea*. It remains for future investigation to determine whether this type of stoma occurs in all Proteaceae; the demonstration of the subsidiary cells is not always an entirely simple matter, since the whole of the stomatal apparatus (i.e. the guard-cells with the subsidiary cells) is frequently depressed. The mode of insertion of the stomatal apparatus in the epidermis has much less systematic importance. In the great majority of species the guard-cells are situated at the same level as the adjacent epidermal cells, or somewhat higher; in the latter case the guard-cells are frequently distinguished by the marked development (strong in *Leucadendron decorum*, less so in *Grevillea Hilliana*) of their outer cuticular ridges, amounting to the formation of a rampart of cuticle. In the species of *Banksia* and *Dryandra* (according to Mohl) and *Lambertia* (according to Engler [1]) the pairs of guard-cells have the same structure as that just described; in these cases several stomata occur together in ampulliform depressions in the surface of the leaf, the depressions being lined with delicate felted hairs. In other species (e.g. *Petrophila rigida, Protea mellifera, Roupala brasiliensis, Aulax umbellata*, according to Tschirch) the guard-cells and epidermal cells lie at the same level and both have their external walls considerably thickened and to an equal extent; consequently the cuticular ridge is raised, and the vestibule correspondingly elongated. Finally, in other species the guard-cells with the subsidiary cells belonging to them are depressed to a greater or less depth below the level of the epidermis of the leaf, and the epidermal cells, which adjoin the stomatal apparatus, form the wall of a variously shaped outer respiratory cavity, the latter being ampulliform (*Franklandia fucifolia*, Fig. 173, *D*), cylindrical (*Stirlingia teretifolia*), funnel-shaped (species of *Hakea*, e.g. *Hakea saligna*) or double funnel-shaped (*Hakea cyclocarpa*). Naturally the stomata may occur on both sides of the leaf (principally in centric leaves), or they may be present on the lower surface only. According to Mohl, they are mostly (with the exception of

[1] In *Lambertia inermis*, R. Br. and *L. multiflora*, Lindl. I did not find this feature; nor did Jönsson in the species of *Lambertia* examined by him.

those occurring in small pits) placed parallel to one another, as in the Monocotyledons, and at the same time parallel to the length of the leaf.

The **hairy covering** consists as a rule of simple, unicellular hairs only, though they vary in other respects. In most cases the hairs have thick walls and narrow lumina, and are stiff; thin, wavy hairs, forming a dense felt, occur in *Banksia* and *Dryandra*; also in *Grevillea Pinaster*, Meissn., according to

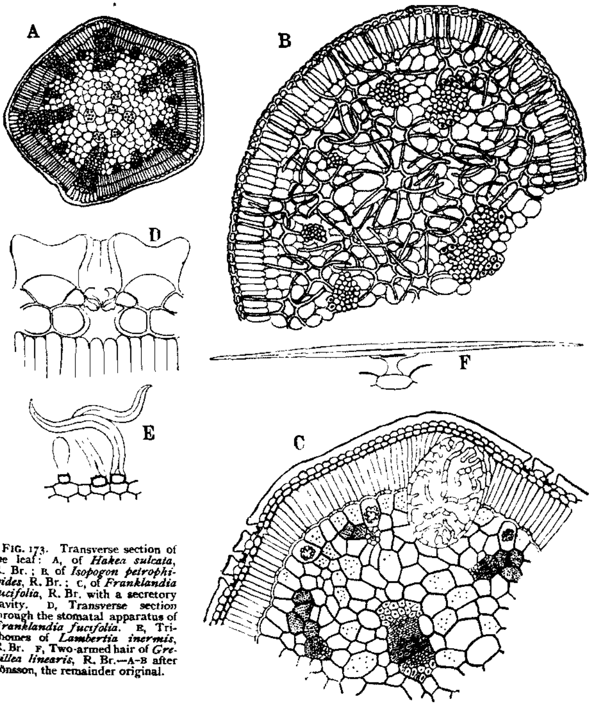

FIG. 173. Transverse section of the leaf: A, of *Hakea sulcata*, R. Br.; B, of *Isopogon petrophiloides*, R. Br.; C, of *Franklandia fucifolia*, R. Br. with a secretory cavity. D, Transverse section through the stomatal apparatus of *Franklandia fucifolia*. E, Trichomes of *Lambertia inermis*, R. Br. F, Two-armed hair of *Grevillea linearis*, R. Br.—A–B after Jönsson, the remainder original.

Engler. The simple hairs, moreover, are not always unicellular; in *Lamberti inermis*, R. Br. (Fig 173, *E*), for example, they consist of quite a short basa cell, inserted on the epidermis, and a long terminal cell with thick walls an narrow lumina. Hairs of a special form appear in the two genera *Grevill* and *Hakea* (according to Möller, Jönsson and Engler). They are bicellula two-armed hairs (Fig. 173, *F*), which are probably to be found in all specie of these two genera, at any rate on some part of the plant. They consist c

a basal and a terminal cell; the former is often long, and sometimes almost without a lumen owing to the strong thickening of the wall; the terminal cell has equal arms, may be thick- or thin-walled, and is pointed at both ends; the middle of the cell is inserted on the basal cell, and its arms either form a wide angle or are directed upwards dichotomously at an angle of 60°–90°. Glandular hairs appear to be absent; an investigation of living material is required to determine whether the hairs, observed by me on the lower surface of the leaf in *Lambertia inermis*, R. Br. (Fig. 173, *E*), and having an ascus-shaped terminal cell and a short basal cell seated on the epidermis, are external glands.

To conclude the section on the structure of the leaf a tabulated review of the more special results obtained by Jönsson is added. Jönsson's types are retained in this review; they are not systematic groups, and transitions between them occur; as regards the species investigated the original work must be consulted.

I. *Hakea*-type. Leaf-structure centric; sclerenchymatous rod-cells in the palisade-tissue: species of *Adenanthos, Grevillea, Hakea, Isopogon, Molloya, Petrophila, Roupala* and *Stenocarpus*.

II. *Isopogon*-type I. Leaf-structure centric; ophiurid-like spicular cells: species of *Isopogon*.

III. *Isopogon*-type II. Leaf-structure centric; ordinary sclerenchymatous cells: species of *Adenanthos, Bellendena, Hakea, Isopogon, Leucospermum, Nivenia, Sorocephalus* and *Xylomelum*.

IV. *Persoonia*-type. Leaf-structure centric; sclerenchyma of the vascular bundles not vertically transcurrent: species of *Adenanthos, Aulax, Conospermum, Embothrium, Leucadendron, Mimetes, Nivenia, Persoonia, Petrophila, Protea, Serruria, Spatalla* and *Stirlingia*.

V. *Synaphea*-type. Leaf-structure centric; sclerenchyma of the vascular bundles vertically transcurrent: species of *Hakea* and *Synaphea*.

VI. *Banksia*-type. Leaf-structure bifacial; sclerenchyma of the veins vertically transcurrent; hypoderm of 1–3 layers: species of *Banksia* and *Dryandra*.

VII. *Grevillea*-type. Leaf-structure bifacial; sclerenchyma of the veins not vertically transcurrent; no hypoderm: species of *Anadenia, Brabejum, Grevillea, Helicia, Lambertia, Lomatia, Orites*.

VIII. *Franklandia fucifolia*, R. Br.: Leaf-structure centric; hypoderm.

IX. *Aulax umbellata*, R. Br.: Leaf-structure centric; between the medulla of the leaf and the palisade-tissue a characteristic layer of cells with brown contents.

3. Structure of the Axis. The structure of the wood has been examined by me in representatives of all the tribes [1], and has also been investigated by Houlbert. The vessels have a maximum-diameter of ·024–·05 mm., and in many cases (in the species of *Banksia, Grevillea, Helicia* and *Lomatia* examined by me, and according to Houlbert in *Banksia, Dryandra, Embothrium, Grevillea, Guevina, Hakea, Knightia, Macadamia, Orites, Roupala, Stenocarpus* and *Xylomelum*, but not in *Brabejum, Isopogon, Persoonia* and *Protea*) they have a characteristic arrangement in the tangential direction, being at the same time embedded in zones of wood-parenchyma similarly situated. The perforations of the vessels are exclusively simple. The vessel-wall is provided with bordered pits where it is in contact with parenchyma. Spiral thickening of the walls of the vessels has been observed in *Dryandra formosa*, R. Br., *Grevillea Baueri*, R. Br. and *Persoonia acerosa*, Sieb. The medullary rays are usually broad; they are narrow, 1–3 cells thick, only in the species of *Franklandia, Persoonia* and *Symphyonema* investigated by me. The wood-prosenchyma is invariably thick-walled, occasionally (*Hakea suaveolens*, according to De Bary) provided with a gelatinous layer, and always bears distinct, though sometimes small bordered pits. On the inner side of the primary vessels groups of sclerenchymatous fibres are developed in many cases (in all the species investigated by me, excepting those of *Symphyonema* and *Persoonia*; see also Vesque, loc. cit. and Baillon, Hist. d. pl., t. ii, p. 406).

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[1] Species of *Protea, Adenanthes, Synaphea, Conospermum, Franklandia, Symphyonema, Persoonia, Helicia, Grevillea, Lomatia, Embothrium, Banksia* and *Dryandra*.

Regarding the structure of the **cortex** our information is still scanty; Möller's investigations extend to species of *Banksia, Hakea, Leucadendron* and *Leucospermum*. The formation of cork takes place subepidermally (species of *Banksia, Grevillea* and *Hakea*, according to Sanio, Möller, Douliot and J. E. Weiss). The differentiated cork consists of cells with thin walls and wide lumina, or of somewhat thick-walled cells. The primary cortex sometimes contains stone-cells; in the pericycle there are isolated groups of bast-fibres. In *Banksia, Leucospermum* and *Leucadendron* the secondary bast is characterized by the following features: the tangential arrangement of compact bundles of hard bast, in addition to which there are smaller isolated groups of hard bast and sclerenchymatous parenchyma with elements of varying shape: the broad medullary rays, which become sclerosed independently of the hard bast; and the sieve-tubes, the elements of which are devoid of sieve-fields only for a short distance in the middle of their length.

Literature: Mohl, Spaltöff. d. Pr., Verh. Leopold. Akad., Bd. viii, 2. Abt., 1833, pp. 789–804 and Tab. lx–lxi, and Verm. Schr., 1845, p. 245 et seq.—Strasburger, Spaltöffn., Pringsheim Jahrb., Bd. v, 1866–7, pp. 328–9 and Tab. xli.—Vesque, in Ann. sc. nat., sér. 6, t. ii, 1875, p. 145.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 42–4 and 338 et seq.—De Bary, Vergl. Anat., 1877.—Areschoug, Blad. anat., Minnesskr. Lund, 1878, p. 125 et seq.—Bengt Jönsson, Bidr. till kännedom. om blad. anat. byggn. hos Pr., Acta Univ. Lund, vol. xv, 1878–9, 49 pp. and 3 Tab.; see also *Just 1880, i*, pp. 113–14.—Tschirch, Assimilationsorg., Linnaea, Bd. 43, 1880–82, p. 139 *et seq.* and Tab. ii.—Möller, Rindenanat., 1882, pp. 119–24.—Solereder, Holzstr., 1885, pp. 228–30.—O. Bachmann, Schildh., Flora 1886, sep. copy, p. 16.—Douliot, in Ann. sc. nat., sér. 7, t. x, 1889, pp. 331–2.—J. E. Weiss, Korkbild., Denkschr. Regensb. bot. Gesellsch. 1890, sep. copy, p. 55.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 (1894), pp. 120–2.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 13–43 and pl. i–ii.—Reiche, in Engler, Jahrb., Bd. xxi, 1895, p. 37 and Chilen. Holzgew., Pringsheim Jahrb., Bd. xxx, 1897, p. 92.—[Tassi, Le Proteacee, Bull. del Lab. ed Orto bot. della Univ. di Siena 1898, pp. 67–134, 13 tav.]

THYMELAEACEAE.

1. Review of the Anatomical Features. This Order is characterized in a most excellent manner by the structure of the stem. In all the genera, with the single exception of *Drapetes*, there is intraxylary phloem [1], accompanied by more or less abundant hard bast-fibres, and the external bast is likewise distinguished by the presence of numerous bast-fibres. The following features may also be described as general anatomical characters of the Order: the superficial development of the cork, the simple perforations of the vessels, wood-prosenchyma with bordered pits, narrow medullary rays in the wood, the absence of external and internal glands, and the lack of a special type of stoma. Oxalate of lime is deposited in very different forms, namely as ordinary solitary crystals, styloids, clustered crystals and crystal-sand; these forms have no great systematic importance. The trichomes are simple and unicellular; hairs of a special form, viz. two-armed hairs, have only been observed in *Daphnopsis*. Interxylary in addition to the intraxylary phloem is present in six genera, namely *Linostoma, Lophostoma, Synaptolepis, Aquilaria, Gyrinops* and *Gyrinopsis*; it is given off internally by the cambium. The following are special anatomical features, which are of value for specific or generic diagnosis: the gelatinization of the epidermis of the leaf and stem, occurring in very many cases; papillose differentiation of the epidermis of the leaf (species of *Daphne*); the occurrence of stomata exclusively on the upper surface of the leaf (species of *Passerina*); the enclosure of the individual stomata in receptacles formed by the papillose elevation of the neighbouring cells (species of *Edgeworthia, Enkleia, Lasiosiphon, Linostoma, Lophostoma* and *Synaptolepis*); scleren-

[1] In *Aquilaria Agallocha*, Roxb. the internal groups of soft bast become transformed by secondary changes into inversely orientated medullary vascular bundles (see below).

chymatous fibres in the mesophyll (species of *Daphne, Daphnopsis, Enkleia, Lasiosiphon, Lophostoma, Peddiea, Stephanodaphne*); finally, the occurrence or absence of intraxylary phloem in the midrib of the leaf and in the petiole, and also the epidermal or subepidermal origin of the cork (according to Van Tieghem).

2. STRUCTURE OF THE LEAF. The structure of the leaf and axis is well known from the investigations of Van Tieghem and Supprian.

The **leaf-structure** is bifacial in most cases. The palisade-tissue generally consists of short cells; the spongy tissue has large or small intercellular spaces. Centric leaf-structure with development of palisade-tissue on both sides of the leaf has been demonstrated in species of *Pimelea, Thymelaea, Stellera* and *Diarthron*; a mesophyll composed of isodiametric cells has been found in species of *Drapetes*. In certain species the mesophyll is traversed quite irregularly by sclerenchymatous fibres (*Daphnopsis Guacacoa*, Wright ed. Griseb. according to Radlkofer; species of *Enkleia, Daphne* section *Eriosolena, Lophostoma, Peddiea* and *Stephanodaphne* according to Van Tieghem; *Daphne pendula*, Sm., *D. Wallichii*, Meissn., *Lasiosiphon scandens*, Endl., *Peddiea Fischeri*, Engl., *P. parviflora*, Hook. f., and *Stephanodaphne cremostachya*, Baill. according to Supprian).

In the leaf the cells of the **epidermis** are generally low; their lateral walls are usually straight on the upper side of the leaf, undulated or straight on the lower side. *Daphnopsis Humboldtii*, Meissn., *Drapetes Dieffenbachii*, Hook. and *Thymelaea hirsuta*, Endl. possess epidermal cells of greater height; in *Dais cotinifolia*, L. this is only the case above the median vein, while on either side of the latter the epidermal cells gradually decrease in height. Epidermal cells having their walls arched outwards are found in species of *Linostoma*; papillose epidermal cells occur on the lower side of the leaf in *Daphne* '*composita*' and *D. involucrata* (Van Tieghem). The thickness of the outer wall varies in relation to climate and habitat. The cuticle is usually smooth; excretion of wax is rare, and the amount of it is never considerable (*Lagetta, Pimelea*). Gelatinization of the inner membranes of epidermal cells, on the other hand, is very common. Mucilaginous epidermal cells in the leaf have been observed by Radlkofer, Bokorny, A. Wagner, Van Tieghem and Supprian in species of the following genera: *Arthrosolen, Chymococca, Cryptadenia, Daphne, Diarthron, Dicranolepis, Edgeworthia, Gnidia, Lachnaea, Lagetta, Lasiadenia, Lasiosiphon, Leucosmia, Linodendron, Linostoma, Lophostoma, Ovidia, Passerina*[1], *Peddiea, Phaleria, Pimelea, Stellera, Struthiola, Synaptolepis, Thymelaea*, and *Wikstroemia*[2]; in some cases they give rise to transparent dots in the leaf. The gelatinization of the internal membranes is often considerable; sometimes a few unchanged cellulose lamellae still remain in the gelatinized membrane (*Arthrosolen gymnostachys*, C. A. Mey. and *A. somalensis*, Fig. 174, *A*, according to Supprian and Van Tieghem respectively). It may be added that, according to Van Tieghem, cells with mucilaginous inner membranes sometimes occur also in the epidermis of the stem (*Arthrosolen, Diarthron*, species of *Gnidia* section *Phidia*, species of *Stellera* section *Dendrostellera*, species of *Thymelaea* section *Lygia*), or in the subepidermal layer of cells in the stem (species of *Phaleria*). The structure of the epidermis of the leaf in *Phaleria coccinea*, Baill. and *P. octandra*, Baill. deserves special notice; in the first of these species epidermal cells with their walls uniformly and strongly thickened occur scattered amongst the ordinary epidermal cells on both sides of the leaf; in the second

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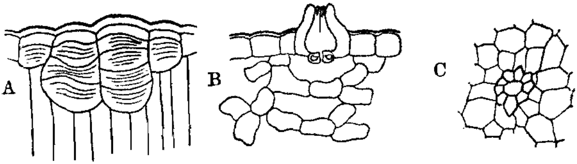
[1] De Bary's statement regarding division of the epidermal cells by means of horizontal walls in *P. ericoides* (p. 35) is erroneous, and referable to the gelatinization referred to above.

[2] Van Tieghem (loc. cit.) goes too far in ascribing generic value to the gelatinization, without having examined a sufficient number of species; in general the occurrence of mucilaginous epidermal cells is only a specific character.

species these cells are only present on the upper side of the leaf. The **stomata** are generally found either on both surfaces or only on the lower. In ***Passerina ericoides, P. filiformis*** and ***P. hirsuta***, the leaves, which are adpressed to the branch, bear stomata on the upper side only; the tissues of the leaf have corresponding positions, the palisade-tissue being situated on the lower (external), and the spongy tissue on the upper side (Caruel). The stomata, as far as I have ascertained, possess no special subsidiary cells (*Daphne Laureola, Aquilaria Agallocha*). They may either lie at the same level as the epidermis, or may be depressed, or rarely (*Passerina*) somewhat raised. Peculiar stomata (Fig. 174, *B–C*), viz. such as occur singly at the base of flask-shaped receptacles, of which the wall is formed by the elongated cells (six to ten in number) adjoining the guard-cells, are present in *Enkleia malaccensis*, Griff. (according to Van Tieghem), *Linodendron* (according to Radlkofer), *Linostoma decandrum*, Wall., *Lasiosiphon scandens*, Endl., *Lophostoma calophylloides*, Meissn., *Synaptolepis Kirkii*, Oliv. and *Edgeworthia Gardneri*, Meissn. (according to Supprian).



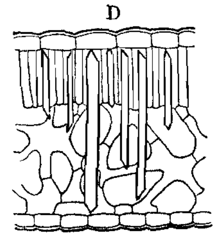


FIG. 174. A. Mucilaginous epidermal cells in the leaf of *Arthrosolen somalensis*. B–C, Stomata enclosed in receptacles: B, in transverse section; C, surface-view. D, Transverse section of the leaf of *Dicranolepis Benthamiana* with styloids.—A and D after Van Tieghem, B–C after Supprian.

The vascular bundles of the **veins** of the leaf are invariably accompanied by bast-fibres (Supprian). Bundles of hard bast occur at the margin of the leaf in species of *Daphnopsis, Dicranolepis, Passerina* and *Synaptolepis*.

Neither internal **secretory organs** nor external glands are present. The **hairy covering** in all cases consists of unicellular trichomes, according to Supprian. A special form of these is constituted by the two-armed hairs, which, according to Radlkofer, occur only in *Daphnopsis Guacacoa*, Wright, while in *D. cuneata*, Radlk. none but ordinary unicellular trichomes are present; in *D. angustifolia*, Wright ed. Griseb., however, the trichomes of the floral region show a tendency to the formation of two-armed hairs.

Oxalate of lime occurs in the form of ordinary rhombohedral solitary crystals, prismatic crystals of more or less pronounced styloid-like shape (Fig. 174, *D*), clustered crystals, and typical crystal-sand. No very great systematic value should be attached to the various forms of excretion in this Order, which is contrary to the results obtained in other Orders; this conclusion agrees with the statements of Gilg and Supprian, but differs from those of Van Tieghem; I convinced myself of this point during an investigation (undertaken some years ago, but not published) of the structure of the axis in most of the genera of this Order.

It is not a rare occurrence for ordinary solitary crystals to be connected with

typical styloids by transitions in the same species. Clustered crystals, styloids and solitary crystals occur embedded in crystal-sand. Several of these forms of crystals, even the most characteristic types, viz. styloids and crystal-sand, are sometimes found within the limits of a genus in closely related species, or even side by side in the same species. Under these circumstances the employment of the features presented by the crystals for systematic purposes is rendered very difficult. For the actual determination of their systematic value far more extensive investigations than have hitherto been carried out would be necessary; such work would repay none but the monographer, who employs endomorphic to supplement exomorphic characters when distinguishing different genera and species. For the purpose of this book the following table may suffice; it combines Van Tieghem's statements with the results of my own investigation, referred to above. In order to avoid false conclusions when using this tabulated review, it must be pointed out that several forms of crystals sometimes occur side by side in the same species:

I. Clustered crystals have been observed in species of *Pimelea, Schoenobiblos, Daphne, Ovidia, Dirca, Daphnopsis, Lasiadenia, Dais, Edgeworthia, Arthrosolen, Goodallia, Funifera, Lagetta, Cryptadenia, Struthiola, Gnidia, Lasiosiphon, Linostoma, Lophostoma, Enkleia, Synaptolepis, Stephanodaphne; Peddiea, Leucosmia, Phaleria, Pseudais.*

II. Ordinary solitary crystals in species of *Schoenobiblos, Dirca, Daphnopsis, Lasiadenia, Dais, Arthrosolen, Goodallia, Lagetta, Lasiosiphon; Peddiea, Phaleria.*

III. Columnar crystals and typical styloids with intermediate forms in species of *Pimelea, Daphne, Ovidia, Dirca, Daphnopsis, Lasiadenia, Dais, Arthrosolen, Goodallia, Funifera, Lagetta, Cryptadenia, Struthiola, Gnidia, Lasiosiphon, Linostoma, Lophostoma, Dicranolepis, Linodendron, Stephanodaphne; Peddiea, Leucosmia, Phaleria, Pseudais; Aquilaria, Gyrinops, Gyrinopsis.*

IV. Bundles of narrow acicular or prismatic crystals in species of *Dirca* and *Pimelea.*

V. Crystal-sand in species of *Ovidia, Dais, Passerina, Chymococca, Funifera, Cryptadenia, Lachnaea, Gnidia, Synaptolepis; Gyrinops* (namely *Lachnolepis moluccana*, Miq.).

VI. Crystal-sand, enclosing an ordinary solitary crystal or a prismatic crystal, in species of *Schoenobiblos, Daphnopsis, Dais, Lagetta, Phaleria, Pseudais.*

VII. Crystal-sand, enclosing clustered crystals, in species of *Ovidia* and *Phaleria.*

VIII. According to Van Tieghem and Supprian, no crystals are present in species of *Daphne, Thymelaea, Wikstroemia, Stellera, Diarthron, Drapetes.*

Before leaving this subject it may be added that in the tissues of young organs of *Daphne Laureola*, L. peculiar sphaerocrystalline bodies appear on the addition of alcohol; they have been investigated by Hansen and Baccarini.

3. Structure of the Axis. The most important feature is the **intraxylary phloem**, which has been demonstrated by Petersen, Solereder, Supprian, Van Tieghem and Gilg in all the genera with the exception of *Drapetes*. Supprian and Van Tieghem between them have made investigations with regard to this feature in species of almost all the genera of Thymelaeaceae given by Durand, as well as *Linodendron, Lophostoma* and *Enkleia*; the only genera in which they had no material were *Schoenobiblos* and *Goodallia*. For these two genera also I am able to record the occurrence of internal soft bast, having myself examined *Schoenobiblos daphnoides*, Mart. (Herb. Monac.) and *Goodallia guianensis*, Benth. (Herb. DC.); this tissue is also present in the new genus *Englerodendron*, Gilg. A few remarks may be made on the exceptional case of *Drapetes*; the species (of which *D. Dieffenbachii, D. ericoides, D. Lyallii* and *D. muscosus* have been investigated) have a moss-like habit; on the evidence of exomorphic characters *Drapetes* is a true member of the Thymelaeaceae, in spite of the absence of intraxylary phloem and of other anatomical characters, which are otherwise of general occurrence in this Order, and will be referred to later. This is not the place for entering into theoretical speculations as to how far the absence of these anatomical features in *Drapetes* may be explained by mode of life and habit.

The intraxylary soft bast is developed in varied abundance. Very fre-

quently bast-fibres are present at the inner margin of this tissue, and they may also be embedded in it; in the latter case the bast-fibres often have a similar distribution to those in the outer bast. Not uncommonly an increase of the intraxylary phloem takes place by means of a cambial ring appearing at the inner margin of the xylem-ring, e.g. in species of *Daphne* and *Aquilaria*. In *Aquilaria Agallocha*, according to Van Tieghem, this cambium not only produces phloem internally, but also woody tissue externally, so that in this plant we have secondary formation of inversely orientated medullary vascular bundles.

The intraxylary phloem, unlike the same tissue in other Orders in which it occurs, is to be found in the petiole and the midrib of the leaf only in a certain proportion of the genera (Lamounette and Van Tieghem). According to Van Tieghem, the presence or absence of this tissue in the petiole and midrib has systematic value for genera and sections of genera, as the following review shows.

Internal soft bast ('tubes péridesmiques') is not present, according to Van Tieghem, in the vascular system of the petiole and midrib of the leaf in the following genera: *Pimelea* sections *Eupimelea, Thecanthes* and *Gymnococca, Schoenobiblos, Daphne* (excl. section *Eriosolena*), *Ovidia, Dirca, Thymelaea, Dais, Stellera, Arthrosolen, Diarthron, Passerina, Chymococca, Cryptadenia, Lachnaea, Drapetes, Struthiola, Gnidia, Lasiosiphon, Linostoma, Dicranolepis; Pseudais, Peddiea*. Internal phloem ('tubes péridesmiques') is present, on the other hand, in the following genera and sections respectively: *Daphne* section *Eriosolena, Daphnopsis, Lasiadenia, Edgeworthia, Wikstroemia, Funifera, Lagetta, Lophostoma, Enkleia, Synaptolepis, Stephanodaphne, Linodendron; Leucosmia, Phaleria; Aquilaria, Gyrinops, Gyrinopsis*.

The **pith** consists of lignified and unlignified cells. Stone-cells are found in the species of *Drapetes, Lasiosiphon, Linostoma, Lophostoma, Pimelea, Stellera* and *Synaptolepis*.

The structure of the **wood** has been examined in almost all the genera of the Order by Supprian, and by me in the investigations mentioned above. On this subject the following statements may be cited. The vessels in the secondary wood generally form groups of variable size, or rarely (*Thymelaea villosa*, Endl.) radial rows. Their maximum diameter varies between ·02 and ·07 mm. They have exclusively simple perforations, and there are bordered pits on their walls, even on those in contact with parenchyma. Spiral thickening of the walls of the vessels has been observed in species of *Arthrosolen, Dais, Daphne, Daphnopsis, Dirca, Lachnaea, Ovidia, Passerina, Pimelea, Stellera* and *Wikstroemia*. The wood-parenchyma is usually scantily developed, but is somewhat more abundant, and takes the form of tangential bands in *Lagetta lintearia*, Lam., *Dirca palustris*, L. and *Pimelea incana*, R. Br., according to Houlbert. The wood-prosenchyma in most cases has wide lumina and bordered pits. The borders of the pits may be small or large, but even when small they are distinct in section. The following constitute exceptions as regards the pitting of the wood-prosenchyma: *Diarthron vesiculosum*, C. A. Mey., in which the wood-prosenchyma may be described as having simple pits, *Edgeworthia chrysantha*, Lindl. with wood-fibres bearing simple (roundish) and bordered pits, and *Lasiadenia rupestris*, Benth. with short prosenchymatous cells having wide lumina and relatively thin walls, which are provided with simple roundish pits. The medullary rays consist of from one to two rows of cells, rarely as many as four.

Interxylary phloem has been observed in six genera, namely *Linostoma, Lophostoma, Synaptolepis, Aquilaria*[1] (incl. *Aquilariella* and *Lachnolepis*), *Gyrinops* and *Gyrinopsis*. This feature was demonstrated by me (1885 and

[1] The interxylary phloem of *Aquilaria* is wrongly interpreted by Möller (1876).

1890) in *Linostoma decandrum*, Wall.[1], *Lophostoma calophylloides*, Meissn., *L. ovatum*, Meissn., *Aquilaria Agallocha*, Roxb., *A. grandiflorum*, Benth., *A. malaccensis*, Lam., *A. microcarpa*, Baill., *A. Ophispermum*, Poir. (?), *Gyrinops Walla*, Gaertn. and *Gyrinopsis Cumingiana*, Decne., by Van Tieghem in *Synaptolepis Kirkii*, Oliv., *Aquilaria Beccariana*, V. T., *Aquilariella borneensis*, V. T. and *Lachnolepis moluccana*, Miq. The origin of this tissue has been investigated in *Linostoma*, *Aquilaria*, *Gyrinops* and *Gyrinopsis*, and in these it is produced internally by the cambium (Thouvenin, Van Tieghem). It is worthy of remark that in some of the species mentioned (in *Aquilaria Agallocha*, *A. malaccensis*, and *A. microcarpa*, *Gyrinops Walla*; and also in *Lophostoma calophylloides*, according to Van Tieghem) bast-fibres occur in the islands of soft bast in the wood; this is doubtless connected with the abundant development of the hard bast in this Order, for islands of soft bast in the wood do not require any mechanical elements.

In the structure of the cortex the development of the **cork** is specially characteristic. The cork-cambium arises either in the epidermis itself, or in the outermost cell-layer of the primary cortex. Van Tieghem ascribes considerable systematic importance to these two modes of origin, as is evident from the following summary; it remains to be determined whether this view is really correct. The cork-cells are mostly flat, rarely (*Lachnaea* and *Cryptadenia*, according to Van Tieghem) they have rather wide lumina. They have uniformly thickened membranes.

The development of cork in the epidermis has been observed by Van Tieghem in the genera *Daphne* (incl. section *Eriosolena*), *Lasiadenia*, *Dais*, *Edgeworthia*, *Wikstroemia*, *Stellera* (section *Chamaestellera*), *Arthrosolen laxus* (= *Rhytidosolen*, Van Tiegh.), *Lagetta*, *Drapetes* pro parte, *Gnidia* pro parte (*Gnidiopsis*, Van Tiegh.), *Linostoma*, *Lophostoma*, *Enkleia*, *Dicranolepis*, *Synaptolepis*, *Linodendron*; *Leucosmia*, *Phaleria*, *Pseudais*; *Aquilaria* pro parte, *Gyrinops*, *Gyrinopsis*.

The following have subepidermal formation of cork, according to Van Tieghem: *Pimelea*, *Ovidia*, *Dirca*, *Thymelaea*, *Daphnopsis*, *Stellera* (section *Dendrostellera*), *Arthrosolen*, *Diarthron*, *Passerina*, *Chymococca*, *Funifera*, *Cryptadenia*, *Lachnaea*, *Drapetes* pro parte (*Daphnobryon ericoides*), *Struthiola*, *Gnidia* pro parte, *Lasiosiphon*, *Stephanodaphne*; *Peddiea*; *Aquilaria* pro parte (*Aquilariella*, Van Tiegh.).

The **primary cortex** contains strongly developed collenchymatous tissue in *Dirca* (Supprian), palisade-tissue in species of *Gnidia* and *Thymelaea* (Van Tieghem). In a transverse section the groups of bast belonging to the vascular bundles usually become narrower outwards in the form of a wedge, as in the lime, the primary medullary rays between them being correspondingly widened. Primary hard bast occurs in all, secondary hard bast in almost all cases (the only exception known being *Drapetes*). The bast-fibres are generally developed in abundance, and are visible even to the naked eye on breaking a young branch, for they then project as silky fibres at the broken surface. Their arrangement in the secondary bast varies. They are either scattered, or form dendritic figures in the transverse section of the branch, or they give rise to a concentric stratification into hard and soft bast. As regards the structure of the bast-fibres, it may be mentioned that the degree of thickening of the walls varies, the walls may be lignified or unlignified, frequently no pits are present, and septation of the lumina never occurs. Peculiar swellings in the bast-fibres have been observed by Wiesner (Rohstoffe) in *Lasiosiphon speciosus*, Decne., and by Supprian in *Daphnopsis Bonplandii*, Meissn., while the fibres were found by Supprian to have an undulated course in *Peddiea Fischeri*, Engl.

[1] *Linostoma scandens*, Kurz, a species which has often been transferred (Syn.: *Enkleia malaccensis*, Griff., *Lasiosiphon scandens*, Endl. &c.), does not possess these islands of soft bast, at least not in branches from herbarium-material.

Appendix: On the anomalous genera *Octolepis* and *Gonystylus*.

Gonystylus has been split into three genera (*Gonystylus*, *Asc. rum* and *Amyxa*) by Van Tieghem, but this subdivision is unwarranted. The two genera *Octolepis* and *Gonystylus* agree with the Thymelaeaceae in the structure of the bast, the superficial development of cork, the occurrence of simple, unicellular hairs, and the absence of glandular hairs, but are essentially distinguished from them by the absence of the intraxylary phloem and the presence of cells containing mucilage in the parenchymatous tissues of the leaf and axis. The genus *Gonystylus* is especially characterized by secretory cavities, which are apparently lysigenous, and sometimes give rise to transparent dots in the leaf.

The genus *Gonystylus*, in which I was the first to observe secretory cavities and the absence of internal soft bast, has recently been raised to the rank of a separate Order, the Gonystylaceae, and placed near the Tiliaceae. Radlkofer and Van Tieghem have likewise investigated it. Van Tieghem also had the opportunity of examining *Octolepis Casearia*, Oliv. Of *Gonystylus* he had the following material at his disposal: *G. Miquelianus*, Teysm. et Binn., *G. affinis*, Radlk. (Syn.: *G. Beccarianus*, Van Tiegh.), *G. borneensis* (Syn.: *Asclerum borneense*, Van Tiegh.) and *G. pluricornis*, Radlk. (Syn.: *Amyxa kutcinensis*, Van Tiegh.).

The following statements may be added regarding the two genera, taking *Gonystylus* first. The leaf-structure is bifacial. Stomata are only found on the lower side of the leaf; in *G. affinis* they are surrounded by a rosette of somewhat smaller epidermal cells. The epidermis of the leathery leaves of *G. Miquelianus* and *G. affinis* has a remarkable structure; its cells are elongated towards the mesophyll in the form of conical proliferations; some of these cells are sclerosed on all sides, the remainder have mucilaginous inner walls. In *G. borneensis* the mucilaginous epidermal cells alone are present; in *G. pluricornis* both mucilaginous and sclerosed epidermal cells are absent. Secretory cavities and mucilage-cells are found in the mesophyll of all the species. Oxalate of lime is excreted in the form of clustered crystals, and, in the axis, also in the form of solitary crystals according to Möller. As regards the structure of the wood, it may be mentioned that the perforations of the vessels are exclusively simple, and that the wood-prosenchyma, which has wide lumina, is provided with small bordered pits. The development of periderm takes place superficially, in the epidermis or subepidermally (Van Tieghem). In the axis the secretory cavities are found in the primary cortex, the mucilage-cells in the pith and primary cortex.

Octolepis possesses mucilage-cells only which are found in the pith and primary cortex, as well as in the mesophyll, and has no secretory cavities. The cork-cambium arises in the epidermis of the branch in this plant. Oxalate of lime is found in the form of clustered crystals.

Literature: Caruel, Foglie della *Passerina hirsuta*, Nuov. Giorn. bot., vol. i, 1869, pp. 194-5 (there cited: Pasquale, Eterofilla, Diss., Napoli, 1867).—Radlkofer, Monogr. *Serjania*, 1875, p. 103.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 39-42 and 335 et seq.—De Bary, Vergl. Anat., 1877.—Möller, Rindenanat., 1882, pp. 114-16.—Petersen, in Engler, Bot. Jahrb., Bd. iii, 1882, pp. 364-5.—Bokorny, Durchs. P., Flora 1882, p. 359 and sep. copy, p. 16.—Radlkofer, in Sitz.-Ber. Münch. Akad. 1884, p. 487 et seq.—Solereder, Holzstr., 1885, pp. 230-3.—Radlkofer, Durchs. Punkte auf Blättern Sitz.-Ber. Münch. Akad. 1886, pp. 328-30.—Baccarini, Sferocristalli, Malpighia, vol. ii, 1888-9, pp. 13-15.—Lamounette, Liber interne, Ann. sc. nat., sér. 7, t. xi, 1890, pp. 274-5.—Solereder, in Ber. deutsch. bot. Gesellsch. 1890, p. (98) note.—Cohn, *Lagetta lintearia*, Jahresber. schles. Gesellsch. f. vaterl. Kultur 1892, Bot. Sekt., p. 65.—Thouvenin, Struct. des *Aquilaria*, Journ. de Bot., t. vi, 1892, pp. 212-15.—A. Wagner, in Sitz.-Ber. Wiener Akad., Bd. ci, Abt. 1, 1892, p. 515.—Van Tieghem, Struct. des *Aquilaria*, Journ. de Bot. 1892, pp. 217-19; Struct. et aff. des Th. etc., Ann. sc. nat., sér. 7, t. xvii, 1893, pp. 185-294 and Tab. ix; see also Bull. Soc. bot. de France 1893, pp. 65-78.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 83-91.—Supprian, Beitr. z. Kenntn. d. Th. etc., Diss., Berlin, 1894, 52 pp. and 1 Tab., also Engler, Bot. Jahrb., Bd. xviii.—Gilg, Verwandtschaftsverh. d. Thymelaeales etc., Engler, Bot. Jahrb., Bd. xviii, 1894, pp. 542-54, and in Natürl. Pflanzenfam., iii. Teil, Abt. 6a, 1894, p. 217.—Gilg, in Natürl. Pflanzenfam., Nachtr. u. Reg., Teile ii-iv, 1897, p. 231.—Kuhla, Phelloderm, Bot. Centralbl. 1897, iii, p. 199.—J. Möller, Lignum Aloës, Pharm. Post 1897.

PENAEACEAE.

This small Order, which is generally placed in the neighbourhood of the Thymelaeaceae, agrees anatomically with the latter in possessing intraxylary soft bast, simple perforations in the vessels, and wood-prosenchyma with typical bordered pits, as well as in the lack of internal and external glands. It is distinguished from the Thymelaeaceae by the absence of hard bast-fibres, which are often developed in such abundance in that Order. The stomata, like those of the Thymelaeaceae, have no special subsidiary cells. Oxalate of lime is excreted exclusively in the form of clustered crystals. The thick leaves contain fibrous cells, which run irregularly in the mesophyll, and are of two kinds, being either sclerenchymatous fibres having thick walls and narrow lumina, and thus serving for mechanical purposes, or relatively thin-walled fibres, stiffened by means of a spiral band, and apparently constituting a system for water-supply; one, at least, of these two forms of fibrous cells is present in every member of the Order which has been examined.

The structure of the leaf and axis is known in detail from the investigations of Van Tieghem and Supprian[1]. The **leaf-structure** is either bifacial (species of *Glischrocolla*, *Endonema*, and *Penaea*, with a tendency to centric structure in some cases), or centric with palisade-tissue on both sides (species of *Sarcocolla*, *Brachysiphon*, *Stylapterus*). The palisade-tissue consists of short cells; the spongy tissue is composed of small cells and is never very lacunar. The **epidermis** of the leaf invariably consists of one layer, and the cells are frequently filled with brown, tanniniferous contents. The outer wall of the epidermal cells is thick; gelatinization of the inner wall has not been observed in any species belonging to this Order. The cuticle shows reticulate striation in some cases, e.g. *Endonema Thunbergii*, while in *Sarcocolla fucata* it has a granular structure (according to my own observations). In *Endonema retzioides* the cuticle forms well-marked external pegs, situated centrally to the surface of the outer walls of the epidermal cells (Supprian). The **stomata** are either found on both surfaces of the leaf (in species of *Sarcocolla*, *Brachysiphon*, *Stylapterus*, as well as in *Penaea Cneorum* and *P. acutifolia*), or only on the lower surface (in most species of *Penaea*, and in *Glischrocolla* and *Endonema*). As I have been able to convince myself in *Penaea myrtoides*, *Sarcocolla fucata* and *Endonema Thunbergii*, the stomata are not accompanied by any special subsidiary cells, but are surrounded by a varying number of ordinary epidermal cells. We must not omit to mention the peculiar peg-like processes which project into the cavities of the cells adjoining the stomata in *Sarcocolla fucata*, and especially in *Penaea myrtoides* (Fig. 175, *A*); they spring from the vertical cell-walls bordering on the uppermost portion of the respiratory cavity; their function has not been determined. The occurrence in the mesophyll of the two forms of fibrous cells (Fig. 175, *B*), referred to above, is very characteristic of the Order. Both forms are branched and run irregularly through the mesophyll. On reaching the upper and lower epidermis the sclerenchymatous fibres very frequently spread out in considerable numbers, parallel to the surface of the leaf, between the epidermis and palisade-parenchyma. The spirally thickened fibrous cells, on the other hand, mostly become enlarged and terminate in contact with the epidermis.

[1] The following is an enumeration of the species investigated by Van Tieghem, the nomenclature being that of DC. Prodr.: *Penaea acutifolia*, *P. Cneorum*, *P. mucronata*, *P. myrtoides*, *P. ovata*; *Stylapterus fruticulosus*; *Sarcocolla formosa*, *S. fucata*, *S. squamosa*; *Brachysiphon acutus*, *B. imbricatus*, *B. speciosus*; *Endonema retzioides*, *E. Thunbergii*; *Glischrocolla Lessertiana*. The species examined by Supprian are included in this list. I have myself made a casual examination of the structure of the wood in all the species just cited with the exception of *S. squamosa*, and also in *Penaea myrtifolia*, *Stylapterus barbatus* and *S. ericoides*, *Sarcocolla minor* and *Brachysiphon ericaefolius*.

Van Tieghem states that both kinds of fibrous cells occur in the species of ***Penaea***, ***Sarcocolla*** and ***Endonema***, those with spiral thickening alone are found in *Glischrocolla* and ***Stylapterus***, and the sclerenchymatous type alone in ***Brachysiphon***. The only **crystalline elements** occurring in the leaf are clustered crystals. **Trichomes** are very rare in the Order; such as are present being short, simple, unicellular hairs (stem of *Penaea mucronata*).

In the structure of the axis, the first feature to be described is the **intraxylary phloem**, which I was the first to demonstrate in this Order (in 1885). None of the species are without intraxylary phloem, which, together with the pith, generally forms a mass of tissue of rhombic shape in a transverse section of the branch. Whilst the internal phloem in the allied Order Thymelaeaceae is almost always provided with hard bast-fibres, these elements are not present in the Penaeaceae. Only in rare cases (*Penaea mucronata*, L. β *microphylla*, Eckl.) are a few sclerenchymatous rod-cells developed at its inner margin. In all cases the structure of the **wood** shows the characters which I previously indicated as marking the Penaeaceae, though the material then examined was very limited. The medullary rays are invariably narrow (1–2 seriate), and

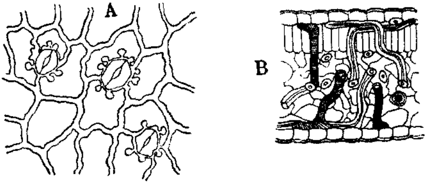


FIG. 175. A, Surface-view of the epidermis on the lower side of the leaf of *Penaea myrtoides*, L. f., seen from within. B, Transverse section through the leaf of *Penaea mucronata*.—A Original, B after Van Tieghem.

consist of cells, which are sometimes considerably elongated in the vertical direction. The vessels have small lumina (maximum diameter = ·022–·04 mm.), and are either isolated or arranged in groups. The perforations are exclusively simple, and the walls of the vessels bear bordered pits, even where they are in contact with parenchyma. The wood-parenchyma is scantily developed. The wood-prosenchyma has typical bordered pits on its walls, which are usually rather thick. The cells of the pith have, for the most part, unlignified walls, and are frequently collenchymatous; scattered stone-cells in the pith are not uncommon. The primary **cortex** usually shows collenchymatous differentiation, and, like the pith, now and then includes stone-cells. The inner limit of the primary cortex is sometimes (*Penaea mucronata*, according to Van Tieghem) formed by a large-celled endodermis provided with Caspary's dots. Bast-fibres are not present in the pericycle nor in the secondary bast. Rod-cells are sometimes developed in place of them, e.g. in the pericycle of *Glischrocolla Lessertiana* or in the secondary bast of *Brachysiphon acutus*. The bast, which is often collenchymatous, generally includes chambered fibres with clustered crystals. The development of cork takes place in the pericycle [1] in *Penaea mucronata*, according to Van Tieghem's and my own observations. The cork is generally composed of two kinds of cells, which sometimes form alternating layers, viz. cells with thin walls and wide lumina, and others with thickened walls and having wide lumina or a tabular form. We may add that in *Endonema retzioides* and

[1] Supprian's statement, that the formation of cork takes place in the subepidermal layer of cells in 'all species,' does not agree with this.

E. Thunbergii small vascular bundles run in the four corners of the stem and bend out into the leaf at the node (Van Tieghem).

Appendix: On the anomalous genus *Geissoloma*, Lindl.

The monotypic genus *Geissoloma* (with *G. marginatum*, Kth.), placed by Bentham and Hooker at the end of the Penaeaceae as a genus anomalum, is probably best regarded as a separate Order in accordance with the views expressed by Sonder and A. de Candolle, since it is essentially distinguished from the Penaeaceae by its endomorphic as well as its exomorphic characters. Thus *Geissoloma* has no bicollateral vascular bundles, but has scalariform perforations with many bars in the vessels, and a composite and continuous sclerenchymatous ring in the pericycle of the axis. In the pitting of the wood-prosenchyma, which is bordered, this genus agrees with the Penaeaceae, as also in the lack of external and internal glands. On the other hand the sclerenchyma-fibres present in the Penaeaceae are entirely absent in the leaf of *Geissoloma*. Oxalate of lime is excreted in the form of solitary and clustered crystals. The trichomes, which occur on the stem, are simple and unicellular.

Van Tieghem and Supprian investigated the leaf and axis of the genus *Geissoloma*; I had only an opportunity of examining the axis. The following statements regarding the anatomy of this genus may be added to those given above. The leaf has bifacial structure. The stomata are only found on the lower surface of the leaf. Both the upper and lower epidermis include numerous mucilaginous cells. The epidermal cells on the upper side of the leaf have strongly thickened outer walls and well-marked cuticular pegs. The peculiar thickened and raised margin of the leaf is formed by higher epidermal cells, thickened on all sides. In the mesophyll clustered crystals are present, according to Van Tieghem. The pith consists of lignified and pitted cells. The medullary rays are 1–3 cells thick, and are formed by cells which are more or less strongly elongated in the vertical direction. The vessels are scattered, and have small lumina (mean diameter = ·025 mm.); their walls for the most part bear large simple pits where they are in contact with medullary ray-parenchyma. In the primary cortex, stone-cells with wide lumina and clustered, and solitary crystals have been observed; in the bast solitary crystals are found. The development of cork takes place in the outermost cell-layer of the primary cortex; the cork-cells have fairly wide lumina.

Literature: Solereder, Holzstr., 1885, p. 233.—Van Tieghem, Sur les Thymélaeacées et les P., Ann. sc. nat., sér. 7, t. xvii, 1893, pp. 277–88.—Supprian, Kenntn. d. Thymelaeac. u. P., Diss., Berlin, 1894, pp. 25–9, also, in Engler, Bot. Jahrb., Bd. xviii.—Gilg, in Natürl. Pflanzenfam., iii. Teil, Abt. 6a, 1894, pp. 206 and 209.

ELAEAGNACEAE.

This Order, which is generally placed near the Thymelaeaceae, is characterized by the following features: the absence of intraxylary soft bast; the presence of simple perforations in the vessels, and of wood-prosenchyma bearing bordered pits; the superficial development of the cork; the occurrence of groups of sclerenchymatous fibres in the pericycle and secondary bast; the lack of a special type of stoma; the nature of the hairy covering, which consists of peltate and stellate hairs; and the excretion of oxalate of lime exclusively in the form of small acicular crystals.

The structure of the leaf and axis has been examined in species of all three genera. The leaves are either typically bifacial (*Shepherdia canadensis*, Nutt.), or tend towards centric structure, the lowest cell-layer of the spongy tissue being, in the latter case, differentiated more or less like palisade (*Hippophaë rhamnoides*, L., *Elaeagnus angustifolia*, L.). Hypoderm has been met with on the upper side of the leaf in *Elaeagnus reflexa* (Lalanne). The stomata, which are surrounded by a varying number of ordinary epidermal cells, are only found on the lower surface of the leaf. The vascular bundles of the veins are not accompanied by sclerenchyma. The covering of stellate and peltate hairs is found in all the

species. The peltate hairs consist of a large number of narrow ray-cells, which have relatively thin walls and wide lumina, and do not all reach the centre of the shield; the ends of the ray-cells are free at the margin of the shield and taper to a point. In *Elaeagnus orientalis*, L. and *E. pungens*, Thunb. an additional tuft of rays is inserted centrally on the upper side of the shield (O. Bachmann). The stalk of the peltate and stellate hairs (these two types being connected by transitional forms) is of very varied length. The long stalks of the hairs of *Shepherdia canadensis* are multiseriate, and consist of rather long cells, replaced immediately beneath the terminal portion of the hair by short cells with yellow walls; in *Hippophaë rhamnoides* (Fig. 176) and *Elaeagnus angustifolia*, on the other hand, the hairs have a short stalk, composed of a single layer of short cells with thick, yellow walls, and giving rise to a false lower scale, when seen in a surface-view of the hair. The mode of excretion of **oxalate of lime** in this Order is very characteristic. Clustered or solitary crystals have not been observed either in the leaf or in the axis. In all cases only small acicular crystals are present; they may be long or short, in the latter case sometimes almost resembling crystal-sand; several of them invariably occur in the same cell. In the leaf they are found in the epidermis and mesophyll, while in the axis they occur in the pith and primary cortex.

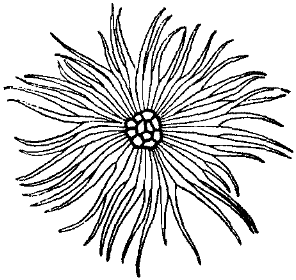


Fig. 176. Peltate hair of *Hippophaë rhamnoides*, L. seen from below.—Original.

Some further information regarding the structure of the **wood** and cortex may be added. The medullary rays of the wood are from one to two cells broad in *Hippophaë* and *Shepherdia*; as much as four cells in breadth in *Elaeagnus*. The vessels attain diameters of ·15 mm. (*Elaeagnus angustifolia*) and ·075 mm. (*Hippophaë rhamnoides*), and are provided with bordered pits, even where they are in contact with parenchyma of the medullary rays. The wood-parenchyma is scantily developed; the wood-prosenchyma[1] is invariably covered with distinct bordered pits, and has more or less thickened walls. The cork arises in the epidermis in *Elaeagnus angustifolia*, and subepidermally in *Hippophaë rhamnoides* (Douliot); it consists of somewhat flattened cells with wide lumina and thin walls. The primary **cortex** is composed of loosely united cells, and even in late stages shows no signs of sclerosis. With regard to the structure of the bast, Möller points out that in *Hippophaë* the bundles of secondary hard bast are irregularly arranged, while the medullary rays are narrow (one or two cells broad), and at some points become sclerosed between the bundles of hard bast; this differs from what is found in *Elaeagnus*, where the hard bast, owing to its regular arrangement, gives rise to stratification of the secondary bast, while the medullary rays are mostly broad and remain thin-walled.

In *Elaeagnus* and *Hippophaë*, according to Mentovich, the **pith** is heterogeneous, and consists of a peripheral portion, in which the cells are smaller, have thicker walls, and are active, and a central cylindrical portion, in which the cells contain no starch, and, after the lapse of a year, are empty.

[1] In the wood-prosenchyma of *H. rhamnoides* (which here has bordered pits), Sanio observed occasional thickenings of the walls, projecting into the cavities in the form of blunt cylindrical pegs, or beams, extending transversely from one side to the other, as in the tracheides of *Pinus silvestris*, &c.

Literature : Rauter, Trichomgeb., Denkschr. Wiener Akad. 1871, sep. copy, pp. 7–8 and Tab. i–ii.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, p. 42 and 338.—De Bary, Vergl. Anat., 1877.—Möller, Rindenanat., 1882, pp. 116–19.—Mentovich, Mark, Klausenburg, 1885; see Just 1885, i, p. 788.—Solereder, Holzstr., 1885, p. 234.—O. Bachmann, Schildh., Flora 1886, sep. copy, p. 17.—Douliot, in Ann. sc. nat., sér. 7, t. x, 1889, p. 332.—Lalanne, Feuilles persist., Actes Soc. Linn. Bordeaux, sér. 5, t. iv, 1890, p. 101 and Pl. vi.—Gilg, in Natürl. Pflanzenfam., iv. Teil, Abt. 3 a, 1894, pp. 246–7.

LORANTHACEAE.

1. Review of the Anatomical Features. According to existing investigations the following anatomical characters should be kept in view for the diagnosis of the Order: the type of stoma, the subsidiary cells being placed parallel to the pore; the position of the stomata on the branch, the stomata being arranged transversely or somewhat obliquely to the longitudinal axis; the simple perforations of the vessels; the isolated groups of bast-fibres in the pericycle; the absence of secondary hard bast; the superficial development of cork; the absence of glandular hairs. The medullary rays of the wood vary in breadth; the wood-prosenchyma generally (exception *Viscum*) bears bordered pits. Oxalate of lime is excreted in the form of ordinary solitary and clustered crystals. The hairy covering (Fig. 177, *B–E*) in *Loranthus* consists of (*a*) uniseriate trichomes, in which each of the cells, with the exception of the terminal cell, is produced at its upper extremity into a lateral protrusion, and (*b*) candelabra-hairs, the tiers of which are unicellular; from analogy the stellate and peltate hairs, mentioned by Engler as occurring in species of *Loranthus*, probably have a unicellular ray-portion and shield respectively. The following special anatomical features have been shown to occur in this Order: cork-warts on the lower side of the leaf in *Loranthus punctatus*, R. et P.; branched or unbranched stone-cells occurring in the tissue of the leaf and cortex in many members of the Order and enclosing solitary crystals (Fig. 177, *A*); frequently swollen tracheae in the terminations of the veins; silicified groups of cells in the leaf-tissue in certain species; lysigenous mucilage-canals in the pith and bast of the axis in *Nuytsia*; groups of sclerenchymatous fibres at the inner margin of the larger vascular bundles in some Loranthaceae; anomalous structure of the axis in *Nuytsia floribunda*, R. Br., consisting in the occurrence of soft bast-tissue in the xylem.

2. Structure of the Leaf. The **leaf-structure** varies; it is sometimes typically bifacial, e.g. in *Loranthus punctatus*, R. et P., sometimes typically centric with palisade-tissue on both sides of the leaf, whilst the mesophyll of *Tupeia pubigera*, Miq. or *Loranthus europaeus*, Jacq. is composed solely of isodiametric cells. In *Viscum album*, L., the leaves of which are biennial, the mesophyll consists of isodiametric cells during the first year; in the second year, however, the layers of cells lying beneath the upper and lower epidermis become elongated like a palisade, and a simultaneous increase in the number of chloroplasts takes place, so that the leaf-structure becomes centric. The **stomata**, as far as is known (in *Arceuthobium*, *Antidaphne*, *Lepidoceras*, *Nuytsia*, *Tupeia*, *Viscum*), are accompanied by subsidiary cells, placed parallel to the pore, only a single subsidiary cell being, as a rule, found on either side of the pair of guard-cells; in rare cases there are several. In leaves with centric or homogeneous structure the stomata occur on both surfaces, being present in smaller numbers on the upper side; in the bifacial leaves of *Loranthus punctatus* they are only found on the lower side, but here they occur in large numbers. The arrangement of the stomata with reference to one another is usually irregular; in *Nuytsia floribunda* alone the stomata are placed transversely to the longitudinal axis of the leaf. On the branches of *Antidaphne*, *Arceuthobium*, *Lepidoceras*, *Loranthus*, *Nuytsia* and *Viscum* the stomata exhibit a similar orientation, i.e. they are arranged

transversely to the longitudinal axis of the branch (Chatin). The outer walls of the cells in the **epidermis** of the leaf as well as in that of the branch are distinguished by their considerable thickness in all the species investigated. I have not observed gelatinization of the epidermis of the leaf in any case, not even in *Nuytsia floribunda*, where it is stated to occur by Van Tieghem. The mechanical system in the **veins** of the leaf is developed in various ways. In *Loranthus punctatus* it consists of strongly developed arcs of sclerenchymatous fibres, whilst in *Viscum album*, *Loranthus europaeus*, *Tupeia pubigera*, &c., an arc of collenchyma is associated with the vascular system of the larger veins; this collenchyma may in some cases (*Viscum album*) subsequently become sclerosed. The occurrence of enlarged terminal tracheides (e.g. in *Viscum album*, *Loranthus europaeus*, &c.), or of independent storage-tracheides in the mesophyll (*Loranthus punctatus*) is very common. Similar water-reservoirs are sometimes found in the form of special systems of tracheae, accompanying the vascular bundles of the veins, e.g. in *Nuytsia floribunda* and species of *Loranthus* belonging to the section *Gaiadendron*, according to Van Tieghem.

Special features in the **mesophyll** are silicified groups of cells and groups of stone-cells with crystalline inclusions; the latter have also been met with in the cortex. The silicified groups of cells in *Loranthus europaeus* were erroneously described by Marktanner-Turneretscher as groups of mucilage cells [1], and their true nature has only recently been recognized by Ravn; they consist of a varying number of cells, which when numerous are often united in the form of a sphere; the contiguous walls of these cells are considerably thickened, stratified and silicified, or they possess silicified protuberances resembling cystoliths, which project convexly into the lumina of the cells and are sometimes stratified. These silicified cell-groups occur principally in connexion with the vascular bundles, and have been observed in the following species, according to Ravn: *Loranthus europaeus*, *Phoradendron emarginatum*, Mart., *P. rubrum*, Griseb., *Stachyphyllum Fendleri*, V. Tiegh., *Tupeia antarctica*, Ch. et Schl., *Viscum album* and *V. articulatum*, Burm. Groups of **stone-cells** appear to be widely distributed in this Order, so far as one can judge from Van Tieghem's investigations, which are not yet completed. They are found, for example, in the tissue of the leaf, and in the pith and cortex of *Loranthus europaeus* (Mentovich, Marktanner-Turneretscher), and, according to my own observations, in the leaves of *L. ferrugineus*, Roxb. (Fig. 177, *A*) and *L. punctatus*, R. et P., and in the cortex of *Tupeia pubigera*. These stone-cells are mostly branched, and ultimately become thickened to such an extent that only one or more peripheral portions of the lumen remain; these are filled by solitary crystals. In the leaf, stone-cells not only accompany the vascular bundles of the veins, but are also found free in the mesophyll (*Loranthus ferrugineus*).

The simplest forms of **trichomes** are uniseriate clothing hairs, in which the upper ends of the cells are produced into lateral processes directed towards the apex of the hair (*Loranthus rufescens*, DC., Fig. 177, *B*). Candelabra-hairs with unicellular tiers are found in the species of *Loranthus* belonging to the section *Cichlanthus* (e.g. *L. ferrugineus*, *L. Scurulla*, L. var. *obtecta*, Kurz, *L. lepidotus*, Bl., &c.), and, according to Engler, also in *Notothixos*. These hairs (Fig. 177, *C–D*) consist of a row of short, and somewhat ventricose, thin-walled cells, in which the wall is protruded, in a horizontal plane at the middle of each cell, into four or more rays; the horizontal walls, separating the individual tiers of the trichome, are pitted. The trichomes found in the floral region of *Loranthus rufescens*, DC. (Fig. 177, *E*) have a structure similar to that of the candelabra-hairs. The peltate and stellate hairs, mentioned by Engler as occurring in

[1] Marktanner-Turneretscher's incorrect interpretation reappears in Haberlandt's Phys. Pflanzenanat., 2nd ed., 1896, p. 353 and fig. 146.

species of *Loranthus* (the former, for example, in *L. Soyauxii*, Engl., the latter in *L. taborensis*, Engl.), may be assumed from analogy to possess a unicellular shield and ray-portion respectively.

The only internal **secretory organs** found in this Order are mucilage-canals, which occur in *Nuytsia floribunda*, R. Br. They appear in the pith, and in later stages in the bast; the pith contains a central mucilage-canal, and others

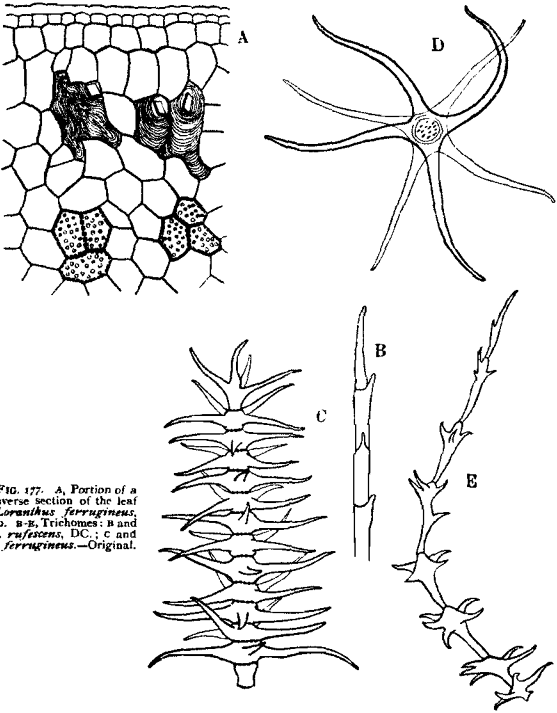


FIG. 177. A, Portion of a transverse section of the leaf of *Loranthus ferrugineus*, Roxb. B-E, Trichomes: B and E, *L. rufescens*, DC.; C and D, *L. ferrugineus*.—Original.

which are peripheral, and situated opposite the larger vascular bundles. The peripheral canals pass out into the midrib of the leaf with the vascular bundles, retaining their position on the upper side of the latter; they do not appear to undergo any further branching, but become considerably swollen at certain points. The mucilage-canals of *Nuytsia* are provided with an epithelium of several layers, but are nevertheless of lysigenous origin; in the leaf the middle

lamellae of the gelatinized cells, which form the canal, can still be clearly recognized.

3. Structure of the Axis. The axis, excepting that of *Nuytsia*, has normal structure. The formation of cork generally (*Loranthus*, *Nuytsia*, *Tupeia*) takes place superficially, whilst in *Viscum*, as is well known, no cork is produced. The primary **cortex** is frequently (*Nuytsia*, *Viscum*) developed as assimilatory tissue, and its outer portion contains palisade-parenchyma in *Nuytsia*. Stone-cells are not uncommonly present in the primary cortex (*Loranthus*, *Tupeia*, *Viscum*), their lumina in some cases containing solitary crystals. Isolated groups of hard bast are found in the pericycle in the species of *Antidaphne*, *Arceuthobium*, *Gaiadendron*, *Lepidoceras*, *Loranthus*, *Nuytsia*, *Tupeia* and *Viscum*, which have been investigated. No secondary hard bast is formed. The structure of the **wood** has been examined in *Viscum album*, L., *Loranthus pentapetalus*, Roxb., *L. europaeus*, Jacq., *Tupeia pubigera*, Miq. and *Nuytsia floribunda*, R. Br. The breadth of the medullary rays varies even within the genus *Loranthus*, *L. europaeus* having very broad rays, while those of *L. pentapetalus* are only from one to three cells in breadth. Engler mentions medullary rays which are only 1–3 cells thick as occurring in most species of *Loranthus*, *Phthirusa*, *Struthanthus*, *Phrygilanthus* and *Lepidoceras*, and multiseriate medullary rays as present in certain species of *Viscum* and *Loranthus*. As in the case of the breadth of the medullary rays, variation also occurs in the arrangement of the vessels, the size of their lumina, and their abundance. In *Viscum album*, for example, the vessels are very numerous, have small lumina (maximum diameter = ·035 mm.), and resemble tracheids; in *Loranthus europaeus* spirally thickened, pitted vessels with narrow lumina are accompanied by others with somewhat wider lumina (diameter reaching ·045 mm.). The perforations of the vessels are invariably simple. Wood-parenchyma is rather abundantly developed. The wood-prosenchyma bears bordered pits in *Loranthus*, *Tupeia* and *Nuytsia*, while in *Viscum* it is scantily developed and sclerenchymatous, and has simple pits. At the inner margins of the bundles of primary xylem massive groups of sclerenchymatous fibres, resembling hard bast, sometimes occur (*Viscum album*; *Antidaphne viscoidea*, according to Chatin; *Nuytsia floribunda*, according to Van Tieghem; *Phoradendron*, according to Engler).

The **pith** consists of collenchymatous cells in *Viscum album* and in the young branches of *Loranthus europaeus*; the cells become lignified in older branches of *Loranthus* (Mentovich).

It now remains to describe (*a*) the curious appearance presented by the stem of *Arceuthobium Oxycedri* in transverse section (quoting from Solms-Laubach's account), the peculiarities being probably shared by other species of the genus, and (*b*) the anomalous structure of the axis of *Nuytsia floribunda*, discovered by Van Tieghem. A transverse section through an internode of *Arceuthobium Oxycedri* shows four vascular bundles, which lie in pairs opposite one another, one pair being more strongly developed than the other. This structure is connected with the course of the bundles (see loc. cit.). The **anomalous structure** of *Nuytsia* consists in the occurrence of bands of soft bast in the xylem. Van Tieghem, who examined young branches in the living condition, came to the conclusion that the interxylary phloem of *Nuytsia* originates in the same way as in *Strychnos*. Older portions of the stem apparently show the anomaly of successive rings of growth; this is illustrated by a specimen which lies before me; it is 10 cm. in diameter, and was presented to our Museum by F. v. Müller. The xylem is traversed by concentric layers of thin-walled tissue, which consists chiefly of large parenchymatous cells and includes mucilage-canals, as well as small groups of soft bast; the latter project convexly on the outer side, and correspond to the individual segments of the xylem-rings, these being limited laterally by broad, lignified medullary rays; these bands of thin-walled tissue

are moreover traversed by the broad lignified rays, which continue their course outwards in the next xylem-ring. These facts are not opposed to Van Tieghem's observations, especially if one bears in mind that the anomalies of successive rings of growth in the pericycle, and of interxylary phloem of the type found in *Strychnos*, are very closely related; for in the first case extinction and extra-fascicular renewal of the cambium take place simultaneously at all points, while in the second case they only occur at certain points in the transverse section.

Literature: [Unger, Parasit. Pfl., Ann. Wiener Mus., Bd. ii, 1840, p. 32, Tab. iii.]—Solms-Laubach, Parasit. Ph., Pringsheim Jahrb., Bd. vi, 1867–8, pp. 603 and 615 et seq. and Tab. xxxix.—De Bary, Vergl. Anat., 1877.—Hesselbarth, Anat. d. Holzes, Diss., Leipzig, 1879, p. 71.—Mentovich, L.-Rinden (Hungarian), Magyar Növenyt. Lapok, vii, 1883, n. 74, pp. 17–23; abstr. in Bot. Centralbl. 1883, ii, pp. 74–5, and Just 1883, i, pp. 180–1.—Solereder, Holzstr., 1885, pp. 234–5.—Mentovich, Mark, Klausenburg, 1885; abstr. in Just 1885, i, p. 788.—Marktanner-Turneretscher, Anat. Bau uns. L., Sitz.-Ber. Wiener Akad. 1885, 12 pp. and 1 Tab.—Van Tieghem, *Nuytsia* et *Gaiadendron*, Bull. Soc. bot. de France 1893, pp. 317–28; *Nallogia* et *Triarthron*, loc. cit. 1894, pp. 61–71; Rac. des L., loc. cit. 1894, p. 121 et seq.; see also loc. cit., 1895.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 (1894), pp. 158–9 and L. africanae, Engler, Bot. Jahrb., Bd. xx, 1895, p. 77 et seq., Tab. i–iii, especially ii.—Diels, Neuseeland, Engler, Bot. Jahrb., Bd. xxii, 1896, p. 240.—Kolpin Ravn, Cystolithes rudim. silicifiés chez qu. L., Bot. Tidsskrift, Bd. 21, i, 1897, pp. 53–8.

SANTALACEAE.

1. Review of the Anatomical Features. The following anatomical features may be pointed out as important diagnostic characters of this Order (excluding the genera *Champereia*, *Grubbia* and *Myzodendron*, which will be discussed separately in an appendix to the Order): the superficial origin of the cork; the uniform structure of the wood, viz. (*a*) vessels with simple perforations throughout, and with the walls usually bearing bordered pits, even where they are in contact with parenchyma of the medullary rays, and (*b*) wood-prosenchyma bearing bordered pits; the almost exclusive occurrence of parallel subsidiary cells on either side of the pair of guard-cells; the fact that the smaller veins of the leaf are invariably embedded; the absence of gelatinization in the epidermis of the leaf, and of internal and external glands; the frequent occurrence of groups of silicified cells, and the excretion of oxalate of lime in the form of clustered and ordinary solitary crystals. These, which are the most important features, are supplemented by a number of others, affording characters for generic and specific diagnosis. Such are: the frequent occurrence of isolated bundles of primary hard bast in the pericycle, whilst a composite and continuous ring of sclerenchyma is rarely (*Henslowia*, and also in *Champereia* and *Grubbia*) present; the very rare development of secondary hard bast (*Santalum*, *Omphacomeria*); the scantiness of the hairy covering, both as regards the actual occurrence of trichomes and the number of forms of hairs present, the hairs being mostly simple and unicellular, rarely (species of *Buckleya* and *Pyrularia*) simple and uniseriate, or still more rarely (*Exocarpus latifolius*, R. Br.) tufted; the enlarged terminal tracheids occurring in many members of the Order, and the rows of tracheids found in the leaf-tissue in some genera (*Quinchamalium*, *Thesium*); the papillose differentiation of the epidermis of the leaf; the occurrence of hypoderm in the leaf; the transverse position of the stomata on the leaf and axis, and so on.

A few facts concerning the three anomalous genera referred to above may be mentioned here. The genus *Myzodendron* is distinguished by the special structure of its xylem and by the occurrence of medullary vascular bundles (Fig. 178) in certain species; another distinctive feature is the absence of parallel subsidiary cells accompanying the stomata. *Champereia* is characterized by the occurrence of double cystoliths (Fig. 179). *Grubbia* differs essentially from the structure typical of the Santalaceae in having scalariform

perforations with numerous bars in its vessels, and in the absence of the parallel subsidiary cells which accompany the guard-cells in the Santalaceae.

2. STRUCTURE OF THE LEAF. The structure of the leaf and axis in this Order have recently been made the subject of a detailed investigation by Behm; his statements are supplementary to the illustrations in Chatin's Atlas [1].

The structure of the leaf varies, and is only of importance for specific diagnosis; it may be either bifacial or centric; in many cases the mesophyll consists of uniform, approximately isodiametric parenchymatous cells. The structural features of the **epidermis** are of greater systematic value. Gelatinization of the epidermis has not been observed in the leaf of any member of the Order; nor are the lateral walls of the epidermal cells ever strongly undulated. The outer wall is often considerably thickened, and the cuticle is not uncommonly striated. In *Cervantesia tomentosa*, Ruiz. et Pav. the upper side of the leaf has specially high epidermal cells, elongated like a palisade, and having a thick outer wall; the lumen is narrowed conically towards the exterior, and contains a deposit of fat-bodies. Papillose differentiation of the epidermis, or the development of a hypoderm, are characteristic of a large number of species. Behm mentions the occurrence of papillae in species of *Arjona, Exocarpus, Leptomeria, Quinchamalium, Santalum* and *Thesium*; their development extends for the most part only to single epidermal cells, or to groups of such cells, which are either situated on the surface or confined to the margin of the leaf; papillose differentiation of the whole of the lower epidermis appears only to have been observed in *Santalum album*, L. According to Behm, the development of **hypoderm** is found in *Henslowia* (*H. granulata*, Hook. fil. et Th., *H. heterantha*, Hook. fil. et Th., *H. retusa*, Bl., *H. varians*, Bl.), in *Jodina rhombifolia*, Hook. et Arn. and in *Santalum acuminatum*, A. DC. (and also locally in *S. Preissianum*, Miq.). In *Henslowia* and *Santalum acuminatum* the hypoderm is composed of somewhat collenchymatous cells, which are larger than those of the epidermis; it consists of two layers in *Henslowia*, of one layer in *Santalum acuminatum*. In *Jodina rhombifolia* the strongly collenchymatous hypoderm and the epidermis together give one the impression of a many-layered epidermis, when seen in transverse section. The structure of the **stomatal apparatus** is, on the whole, uniform; each pair of guard-cells is generally accompanied on either side by one or more subsidiary cells, placed parallel to the pore. It should, however, be mentioned that the type of stoma just described is sometimes less distinctly marked, even in the same superficial section, owing to the fact that secondary vertical walls, running at right angles to the pore, more or less frequently arise in the subsidiary cells. Actual exceptions to the characteristic type of stoma are, however, only afforded by species of *Arjona* and *Quinchamalium*, in which the same superficial section shows stomata with parallel subsidiary cells accompanied by others, which are surrounded by a relatively large number of adjacent cells exhibiting no special arrangement. The arrangement of the stomata with reference to one another is also of value for the recognition of certain genera and species. In some cases they are placed parallel to one another and transversely to the midrib of the leaf; this arrangement is well marked, according to Behm, in species of *Exocarpus, Leptomeria, Omphacomeria, Osyris, Santalum* and *Thesium*, and, according to Chatin, in *Anthobolus* and *Chorethrum*, whilst, according to Behm, in other species of *Osyris* and in species of *Comandra* and *Osyridicarpus* the tendency towards transverse arrange-

[1] Behm examined numerous species of the genera *Quinchamalium, Arjona, Thesium, Osyridicarpus, Cervantesia, Jodina, Pyrularia, Acanthosyris, Comandra, Santalum, Myoschilos, Buckleya. Osyris, Omphacomeria, Henslowia, Choretrum, Leptomeria, Exocarpus*; Chatin, besides dealing with species of certain of the genera already mentioned, has also figured the structural features of *Nanodea, Fusanus* (*Mida*) and *Anthobolus*.

ment of the guard-cells is only seen here and there. In other cases, which are restricted to the genus *Arjona*, the pairs of guard-cells are likewise arranged parallel to one another, but at the same time they lie parallel to the midrib of the leaf. In other cases again we have an irregular arrangement of the pairs of guard-cells, this being the most widely distributed type (in species of *Acanthosyris, Buckleya, Cervantesia, Exocarpus, Henslowia, Jodina, Myoschilos, Pyrularia, Quinchamalium* and *Santalum*, according to Behm). A transverse arrangement of the stomata, similar to that shown by the leaves, occurs also on the young branches in many members of the Order ; Chatin mentions this feature as being more or less distinct in species of *Anthobolus, Choretrum, Fusanus, Henslowia, Myoschilos, Osyris* and *Thesium*, whilst De Bary mentions its occurrence in *Exocarpus* and *Santalum*, and Hieronymus in *Jodina* and *Leptomeria*. The stomata either occur on both sides, or only on the lower surface of the leaf. The guard-cells in most cases lie on a level with the epidermis, but they have been observed to be deeply depressed in *Arjona, Jodina* and *Osyris*. The vascular bundles of the **veins**, as stated above, are invariably embedded; mechanical tissue may accompany them, or may be absent. The **terminal tracheids**, previously mentioned in the general diagnosis, are found in most of the genera ; amongst the genera examined by Behm, they are only absent in *Acanthosyris, Buckleya* and *Jodina*. They form groups of two to five elements, and are developed in a specially typical manner in *Henslowia*. In *Quinchamalium* and *Thesium*, besides the terminal tracheids, there are others, which are independent of the veins, and form rows of elements running parallel to the latter ; these tracheids are more or less elongated, and their walls either have bordered pits, or are spirally or reticulately thickened.

Regarding the occurrence of **oxalate of lime**, we may mention once more that clustered and ordinary solitary crystals occur in both the leaf and axis. According to Behm, certain species of *Cervantesia* and *Leptomeria* have specially large clustered crystals in the leaf. In *Santalum album*, L. and *Jodina rhombifolia*, Hook. et Arn. solitary crystals are found in the epidermis of the leaf ; in the case of *Jodina rhombifolia* they appear, on superficial observation, to lie in the considerably thickened outer wall of the epidermis. Behm also notes the presence of crystalline, in some cases sphaerocrystalline, doubly refractive masses in the epidermal cells of *Thesium montanum*, Ehrh., *T. ebracteatum*, Hayne, and *Santalum acuminatum*, A. DC. ; in view of their solubility in alcohol and ether, these masses are probably of a fatty nature. Behm observed groups of silicified cells in species of *Acanthosyris, Buckleya, Comandra, Exocarpus, Osyris, Pyrularia* [1], *Quinchamalium, Santalum* and *Thesium*. They are present chiefly in the neighbourhood of the veins, and either consist of pairs of cells, or of larger groups. The walls of the cells in question either exhibit silicified protuberances (often hemispherical), or they are only locally thickened (like a horseshoe, as seen in transverse sections of the leaf) and silicified.

The most important points concerning the **hairy covering** have already been stated above. In most cases the simple unicellular hairs are small and pointed. Uniseriate hairs are mentioned by Behm as occurring in *Buckleya lanceolata*, Miq. (incorrectly named *B. Quadriala*, S. et Z. by Behm), and are also present in *Pyrularia*, according to Chatin. The tufted hairs of *Exocarpus latifolius*, R. Br. consist of short unicellular hairs having thick walls and narrow lumina, and sunk side by side in the epidermis.

3. Structure of the Axis. The most important characters presented by

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[1] These groups of silicified cells were previously seen by Bokorny in *P. pubera*, Michx., where they give rise to transparent dots at the margin of the leaf, but they were not correctly interpreted by him.

the structure of the wood and cortex have already been pointed out in the general review at the beginning of the Order.

The structure of the axis is normal. The xylem-portions of the vascular ring as a rule form a closed mechanical ring, traversed by medullary rays which are mostly narrow, though occasionally (in species of *Acanthosyris*, *Osyridicarpus*, *Osyris*, *Jodina*) rays 4–5 cells thick are present. Exceptions to this type are presented by some herbaceous species, viz. *Nanodea*, in which, according to Chatin, the transverse section of the stem exhibits four isolated vascular bundles, arranged in a ring, and species of *Thesium* and *Arjona*, in which the bundles of the vascular ring are separated from one another by unlignified tissue. The **phylloclades** of the leafless species or of those with reduced leaves (*Exocarpus phyllanthoides*, Endl., *Omphacomeria psilotoides*, A. DC.) possess a vascular ring, the bundles of which are almost compressed into one plane in *Exocarpus*, whilst in *Omphacomeria* three larger bundles, which form a ring open at the sides, are seen in the middle of the main vascular ring; in other respects the phylloclades have the structure of a centric leaf.

The **pith** consists either of lignified or unlignified cells. The **vessels** are scattered in the transverse section, and have relatively small lumina (between ·018 and ·03 mm.). In contact with parenchyma of the medullary rays, the walls of the vessels mostly bear bordered pits, though there are sometimes simple pits as well; the latter are never large, and do not exceed the borders of the bordered pits in size. Spiral striation or thickening of the walls of the vessels is stated by Behm to be present in species of *Exocarpus*, *Osyris*, *Santalum* and *Thesium*. The development of cork takes place either in the epidermis (*Acanthosyris* and *Comandra*), or in the outermost cell-layer of the primary cortex (*Buckleya*, *Choretrum*, *Henslowia*, *Leptomeria*, *Myoschilus*, *Osyris*, *Santalum* and *Thesium*). In many of the Santalaceae showing reduction in the leaves, the primary cortex is differentiated as typical assimilatory tissue, as in the phylloclades mentioned above. In some cases the primary cortex includes stone-cells (species of *Choretrum*, *Henslowia*, *Santalum* and *Thesium*), and occasionally there are also bundles of sclerenchymatous fibres (according to Behm, in *Santalum*, and in the shoots of *Omphacomeria* which resemble phylloclades; in these two cases the fibres are mainly subepidermal; according to Chatin, they also occur in *Leptomeria Billardieri*). The outer limit of the bast is in most cases formed by isolated groups of primary bast-fibres, between which scattered stone-cells may occur at some points. The stone-cells are present in such abundance in *Henslowia* that a composite and continuous ring of sclerenchyma is formed. Amongst the material investigated by Behm, the groups of primary bast-fibres are only wanting in the species of *Comandra*; according to Chatin, however, they are present in a species of this genus (*C. livida*), which was not examined by Behm. Typical bast-fibres have only been observed in the secondary bast in the case of *Omphacomeria* and *Santalum* (Behm); the secondary bast contains stone-cells in species of *Osyridicarpus* and *Henslowia* (Behm), and peculiar sclerenchymatous elements, resembling 'both stone-cells and bast-fibres,' in *Exocarpus cupressiformis*, Labill. (Möller [1]).

APPENDIX.

1. On the genus *Myzodendron*.

The parasitic genus *Myzodendron*, which has recently been separated from the Santalaceae and raised to the rank of an independent Order by Hieronymus in the Natürliche Pflanzenfamilien, agrees with the Santalaceae in many of its anatomical characters; thus it has: superficial development of cork; simple perforations in the vessels; no internal or external glands; silicified groups of cells; solitary and clustered

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[1] Regarding the haustoria of the Santalaceae see Solms-Laubach and De Bary, ll. cc.

crystals; isolated groups of hard bast in the pericycle, simple unicellular hairs; again, in one species (*M. lineare*, Pöpp. et Endl.) systems of tracheids are present in the leaf, similar to those of the species of *Quinchamalium* and *Thesium*, and another species (*M. quadriflorum*, DC.) has crystalline masses in the epidermis of the leaf (and also in the ground-tissue of the axis) like those found in *Thesium montanum*, &c. There are only two important anatomical distinctions between *Myzodendron* and the majority of the Santalaceae to be noted, viz.: I. The stomata are surrounded by a rather large number of irregularly arranged epidermal cells. II. The wood-prosenchyma, i.e. when there is any development of mechanical tissue in the xylem, is replaced by sclerenchymatous cells bearing simple pits and resembling rod-cells.

Little remains to be said on the subject of the structure of the **leaf**. The mesophyll consists of uniform isodiametric cells. The stomata are found on both surfaces of the leaf, and are placed parallel to one another and to the midrib of the leaf. The vascular bundles both of the large and small veins are embedded in the mesophyll; there is no sclerenchyma accompanying them. Silicified groups of cells have been observed by Behm only in *M. imbricatum*, Pöpp. et Endl., *M. lineare*, Pöpp. et Endl., *M. punctulatum*, Soland. and *M. quadriflorum*, DC.

The structure of the **axis** requires a more detailed description, and on the characters presented by it the investigated species can be divided into two groups, corresponding to the two sections *Eumyzodendron* and *Gymnophyton*, established by Hooker fil. The species of the section *Eumyzodendron* (*M. brachystachyum*, DC., *M. lineare*, Pöpp. et Endl. = *M. linearifolium*, DC., *M. oblongifolium*, DC., *M. quadriflorum*, DC.) are characterized by the following features: (*a*) the vascular bundles are separated from one another by radial strips of unlignified ground-tissue; (*b*) the ground-mass of the wood consists of unlignified cells and is developed in varying abundance in the different species, depending on the number of vessels and groups of mechanical cells which are embedded in it; and (*c*) the secondary wood contains two kinds of vessels, some being scalariform and others having spiral thickenings. On the other hand the investigated species of the second section (*Gymnophyton*), viz. *M. punctulatum*, Soland. and *M. imbricatum*, Pöpp. et Endl., have the xylem-groups of the vascular bundles united to form a closed mechanical ring, composed of lignified cells only, and traversed neither by primary nor secondary medullary rays. In certain species of the first section, though not in all (only in *M. brachystachyum*, *M. oblongifolium*, *M. quadriflorum*, and also in *M. angulatum*, Phil., according to Hieronymus), **medullary vascular bundles** occur. They are normally orientated, are present in varying abundance, and possess considerable secondary growth in thickness. Not uncommonly they form a second (inner) ring of bundles (Fig. 178, *A*). According to Behm's investigations the medullary bundles are of secondary origin in *M. oblongifolium*. Their development appears to be connected with the formation of pseudoendogenous buds, and this may possibly explain the fact that, according to Behm, in one and the same species the medullary bundles may be present in one branch, though absent in another of equal thickness.

Of the more special anatomical features in the structure of the stem the following are noteworthy. *M. punctulatum* alone has numerous verrucose prominences on the surface of the stem, giving the latter a punctate appearance; hence the specific name. These prominences are due to large respiratory cavities, and each bears a stoma at its apex. The formation of cork is superficial. In most species the cork develops in the epidermis: in *M. oblongifolium* (in the specimen described by Behm as *M. heterophyllum*, Pöpp.), in which the epidermal cells on the young branch are produced into finger-shaped unicellular hairs, it arises in the subepidermal layer of cells. In *M. brachystachyum* and *M. oblongifolium* the primary **cortex** contains a more or less closed ring of stone-cells; in *M. oblongifolium* there are also scattered groups of stone-cells. In *M. lineare* stone-cells are distributed throughout the ground-tissue of the axis, and are also found in the soft bast. In all the species groups of hard bast are present at the outer limit of the phloem, but are developed to a varying extent. The xylem in all species of *Myzodendron* is characterized by the fact that the vessels have relatively small lumina, are composed of short elements, and exhibit simple perforations. In the species belonging to the section *Eumyzodendron*, as already mentioned, the secondary **wood** possesses two kinds of vessels, viz. (*a*) vessels with rather large lumina and provided with scalariform bordered pits, and (*b*) spirally thickened vessels with somewhat narrower lumina; in the species of the section *Gymnophyton*, on the other hand, we only find vessels of the first kind. In

the species of both sections the mechanical elements of the xylem consist of sclerenchymatous cells (' wood-prosenchyma ') resembling rod-cells ; they have thick walls and narrow lumina, and bear simple pits. It has already been stated above that, in the species of the section *Gymnophyton*, these sclerenchymatous cells together with the pitted vessels form a closed woody ring, devoid of medullary rays. In the species of the section *Eumyzodendron*, on the other hand, the ground-mass of the wood in the individual vascular bundles consists of unlignified cells, the bundles being separated from one another by strips of thin-walled tissue. In those species in which material of sufficiently thick branches has been examined (*M. oblongifolium*, *M. brachystachyum* and *M. quadriflorum*, according to Behm, and *M. linearifolium*, according to Hooker and Chatin) it has been found that the vessels and sometimes also the wood-prosenchyma show a very characteristic distribution amongst the unlignified cells in a transverse section of the branch. In *M. oblongifolium* (Fig. 178)

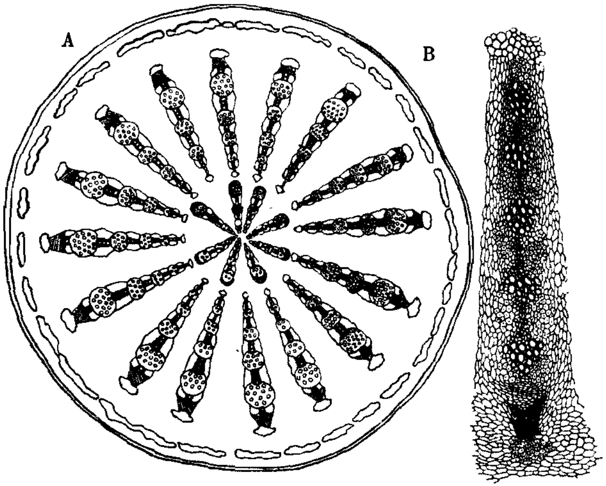

FIG. 178. *Myzodendron oblongifolium*, DC.: A, Diagrammatic representation of a transverse section through the axis ; B, a single vascular bundle.—Original.

each of the individual vascular bundles (including the medullary bundles, when they have undergone considerable growth in thickness) contains groups of scalariform vessels, which are embedded in a small quantity of thin-walled tissue and alternate in the radial direction with portions of tissue composed of spirally thickened vessels, a few thin-walled cells, and the mechanical elements (wood-prosenchyma). In the portions of tissue last mentioned, the arrangement of the elements is as follows : the middle region is occupied by a radial series of the thin-walled cells ; amongst these the spirally thickened vessels are embedded, whilst a bundle of short prosenchymatous cells lies on either side of the radial group. A similar stratification of the secondary wood has also been observed in the other species of the section *Eumyzodendron*, mentioned above, except that the groups of mechanical tissue are only developed at certain points, or are entirely absent. In some species (*M. lineare*, *M. oblongifolium*) bundles of elongated sclerenchymatous cells, resembling hard bast, are found on the inner side of the vascular bundles. The pith as a rule

consists of unlignified cells with thin walls; in the investigated species of the section *Gymnophyton* it is composed of prosenchymatous cells having thick walls.

For the structure of the haustorium of *Myzodendron* reference may be made to Chatin, pl. lxxv.

2. *On the genus Champereia.*

Recent authors refer the genus *Champereia* to the Opilieae (which are provided with cystoliths, according to Edelhoff and Valeton); and like the Opilieae, *Champereia* possesses typical cystoliths, a point to which attention was first drawn by Van Tieghem. These cystoliths cannot, however, be regarded as decisive in determining the systematic position of the genus. For Behm has shown that transitional forms connect the cystoliths with the cystolith-like, silicified protuberances, which occur both in the Opilieae and in the typical Santalaceae.

The **cystolith-like structures** of *Champereia* may be divided into three types. The first consists of true double cystoliths (Fig. 179, *A* and *B*). They were observed by Behm in all the material which he examined; he found them to occur in the bast of the branch, and also in the pith and the tissue of the medullary rays. Instead of two there may sometimes be three or four cystoliths together. The double cystoliths lie in two adjacent cells, which are in contact with one another by their narrow sides,

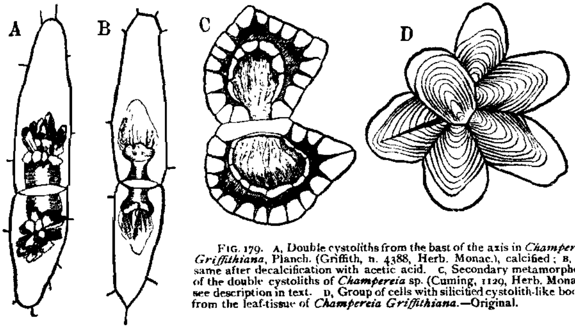

FIG. 179. A, Double cystoliths from the bast of the axis in *Champereia Griffithiana*, Planch. (Griffith, n. 4388, Herb. Monac.), calcified; B, the same after decalcification with acetic acid. C, Secondary metamorphosis of the double cystoliths of *Champereia* sp. (Cuming, 1129, Herb. Monac.), see description in text. D, Group of cells with silicified cystolith-like bodies from the leaf-tissue of *Champereia Griffithiana*.—Original.

the latter being placed horizontally in the pith and bast, and vertically in the medullary rays. The stalks of the two cystoliths, which are mostly calcified, spring from the common wall of contact. The second type is formed by cystolith-like structures, which may be shortly described as cystoliths which are sessile, or devoid of a stalk, and have a reduced skeleton; they have been observed in the primary cortex and in the tissue of the leaf, giving rise to transparent dots in the latter. They form spherical groups of 2–6 cells, each of which contains a body resembling a cystolith. These cells exhibit considerable local thickenings on the walls of contact, and in each cell a crystal of carbonate of lime, having a rather irregular outline and almost filling the lumen of the cell, is inserted in the thickening of the wall like a tooth in the jaw. These characteristic groups of cells, or rather the crystals they contain, together give one the impression of a large clustered crystal, when examined under a low magnification. The third type is formed by silicified protuberances having the shape of a cystolith (Fig. 179, *D*), the lithocysts being arranged in a group, as in the second type, and the group having a more or less spherical shape. Behm only met with this third type in a certain portion of his material, where it occurred in the tissue of the leaf. For the transitions between the three types, observed by Behm, we may refer to his treatise. An interesting metamorphosis of the twin cystoliths and their lithocysts (Fig. 179, *C*), however, must not be omitted here; all stages were observed by Behm in the bast of the material collected by Cuming (n. 1129, Herb. Monac.). This secondary metamorphosis may extend to both or only to one of the cystoliths with

the corresponding lithocysts, and is initiated by the disappearance of carbonate of lime from the cystoliths. At the same time the cell-wall of the lithocyst becomes sclerosed. A further stage is found in those cases in which sclerosis also affects the outer portion of the cystolith, so that one might imagine there were two sclerosed cells, the one inserted in the other (Fig. 179, *C*). Finally, in some cases sclerosis is carried so far that the sclerosed wall of the lithocyst fuses with the sclerosed outer portion of the body of the cystolith to form a homogeneous membrane; in this final stage, therefore, we obtain a stone-cell, the lumen of which still shows the approximate shape of the original cystolith.

The following points are noteworthy in the structure of the **leaf** and **axis** of *Champereia*. The leaf-structure is bifacial. The stomata are only present on the lower side of the leaf, and possess several subsidiary cells, placed parallel to the pore. The vascular bundles of the smaller and larger veins of the leaf are embedded. The xylem is composed of: (*a*) vessels with small lumina (diameter = ·033 mm.), simple perforations, and bordered pitting in contact with parenchyma; (*b*) two- to three-seriate medullary rays; (*c*) wood-prosenchyma with rather thick walls and bordered pits; and (*d*) a small amount of wood-parenchyma. A composite and continuous ring of sclerenchyma is found in the pericycle. The cork arises in the epidermis, and consists of cells with thick walls and narrow lumina.

3. On the genus *Grubbia*.

The genus *Grubbia* has, on the one hand, been referred to the Santalaceae as an anomalous genus, on the other hand it has been associated with other Orders, such as Hamamelidaceae and Bruniaceae, and recently it has also been regarded as a separate Order, the Grubbiaceae. It is essentially distinguished from the Santalaceae anatomically by the occurrence of scalariform perforations in the vessels, and by the absence of parallel subsidiary cells in the stomatal apparatus. Neither have silicified groups of cells, nor terminal tracheids, nor independent rows of tracheids in the leaf-tissue been observed in this genus. Points of resemblance between *Grubbia* and the Santalaceae are the small lumina of the vessels, the wood-prosenchyma with bordered pits, and the superficial formation of the cork.

The following facts may be added regarding the more detailed structure of the **axis** and **leaf**. The leaf-structure is bifacial. The stomata are found only on the lower surface of the leaf, and are surrounded by a relatively large number of irregularly arranged epidermal cells. The wood consists of: (*a*) vessels with small lumina (diameter = ·03 mm.) and scalariform perforations with numerous bars (40 or more), and both simple and bordered pits on the walls in contact with parenchyma of the medullary rays; (*b*) narrow, uniseriate or biseriate medullary rays; (*c*) wood-prosenchyma with bordered pits; and (*d*) a small amount of wood-parenchyma. A composite and continuous ring of sclerenchyma is present at the outer limit of the bast in *Grubbia stricta*, A. DC., while in *G. rosmarinifolia*, Berg there are only isolated groups of hard bast. According to Hieronymus the branch in the species of the section *Ophira* is characterized by a hypoderm, which is sharply differentiated from the internal tissue, whilst in the species of the section *Strobilocarpus* the hypoderm and cortical tissue merge into one another. The cork arises subepidermally and is composed of cells with rather thick walls. Oxalate of lime is found in the form of clustered and solitary crystals. In the leaf of *Grubbia rosmarinifolia* the clustered crystals occur chiefly in septate cells of the palisade-tissue; while in *G. stricta* idioblasts, situated immediately beneath the epidermis of the leaf, contain solitary or more rarely clustered crystals. The hairy covering consists of simple, unicellular trichomes, which sometimes have verrucose thickenings.

Literature: Chatin, Anat. comp., Pl. parasit., 1856–62, pl. lvi–lxxvi a and cx.—Dalton-Hooker, *Myzodendron*, Ann. sc. nat., sér. 3, t. v, 1846, p. 193 et seq. and pl. 5–9, and in Flora antarct., vol. ii, 1844–5, p. 289, Tab. cii–cvii.—Pitra, Phan. Paras., Bot. Zeit. 1861, p. 69.—Solms-Laubach, Paras. Phan., Pringsheim Jahrb., Bd. vi, 1867–8, pp. 539–60 and Tab. xxxii–xxxiii, and abstr. of Clarke, Loranthaceae, Bot. Zeit. 1874, p. 145 et seq.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, p. 39 and 335.—De Bary, Vergl. Anat., 1877.—Möller, Rindenanat., 1882, pp. 113–14.—Bokorny, Durchs. P., Flora 1882, p. 358 et seq. and sep. copy, pp. 15–16.—Solereder, Holzstr., 1885, pp. 235–6.—Radlkofer, in Sitz.-Ber. Münch. Akad. 1886, p. 330.—Hieronymus, in Natürl. Pflanzenfam., iii. Teil, Abt. 1, 1889, pp. 199–200, 204–206 and 229.—Van Tieghem, *Champereia*, Ann. sc. nat., sér. 7, t. xvii, 1893, pp. 255–6.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 165–70.—Van Tieghem, *Nallogia*, Bull. Soc. bot. de France 1894, p. 61 et seq.—Behm, Anat. Charakt. d. S., Diss., Erlangen, 1895, 56 pp., sep. copy from Bot. Centralbl. 1895, ii.—[Engler and Volkens, Ostafr. Sandelholz, Notizbl. bot. Gart. u. Mus. Berlin 1897, n. 9.]

BALANOPHOREAE.

The Balanophoreae, as is well known, are root-parasites devoid of chlorophyll; they will only be treated here as far as is compatible with the object of this book. For information regarding other features the literature cited must be referred to.

The **ground-tissue** in these fleshy plants, which have a yellowish or reddish colour, consists of large parenchymatous cells; these become smaller towards the periphery both in the rhizome and in the peduncles. In the genera *Balanophora, Langsdorffia* and *Thonningia,* this tissue contains a substance [1] first observed by Goeppert, who gave it the name balanophorin; according to Poleck, it is a body having the appearance of wax, but of the nature of resin, and essentially distinguished from wax by its stickiness and higher melting point. In the other genera starch is found in place of the balanophorin. Other special cell-contents in the ground-tissue are the clustered and solitary crystals, met with in *Balanophora alutacea* by Goeppert, and the sphaero-crystalline clusters consisting of oxalate of lime and observed in *Lophophytum mirabile,* Schott et Endl. by Eichler. In certain species (*Helosis guianensis,* Rich., *H. mexicana,* Liebm., *Langsdorffia hypogaea,* Mart., *Lophophytum mirabile,* Schott et Endl., *Rhopalocnemis, Scybalium jamaicense,* Schott et Endl.) stone-cells, which are either isolated or united into groups, occur in the ground-tissue; the cells are sclerosed on all sides, or (*Langsdorffia hypogaea*) on one side only. In the tuberous rhizome of *Lophophytum mirabile* they become secondarily corroded owing to a process of solution, and ultimately become completely dissolved (Eichler).

The **epidermis** consists of small cells, and contains no stomata. In *Balanophora involucrata,* Hook. f. et Th. the epidermis includes cells of a papillose nature, occurring singly or united into groups (Hooker). **Trichomes** are rare (*Langsdorffia, Thonningia*) on the vegetative organs; where present they are unicellular, have thin walls and rather wide lumina, and a bulbous basal enlargement.

The **vascular bundles** are always collateral; the following facts may be mentioned regarding their distribution n the rhizome and peduncle. Owing to the irregular course and the branching of the vascular bundles, their arrangement is irregular in the tuberous rhizomes (*Helosis, Langsdorffia, Lathrophytum, Lophophytum, Rhopalocnemis, Scybalium*) and in the axis of the inflorescence (*Cynomorium, Helosis, Langsdorffia, Lophophytum, Rhopalocnemis, Sarcophyte, Scybalium*). This irregular arrangement is most marked in *Scybalium fungiforme,* Schott et Endl. and *Lophophytum mirabile,* Schott et Endl., in which the number of bundles in the transverse section amounts to 200–300, whilst in the axis of the inflorescence of *Helosis guianensis* one can distinguish two more or less distinct rings of vascular bundles, and in that of *Langsdorffia hypogaea* a main ring with medullary and cortical bundles. The cylindrical rhizomes of *Helosis* and *Langsdorffia* generally have only a single ring consisting of a few isolated vascular bundles; at those points, however, at which local tuberous thickenings occur, the regular arrangement ceases. In the floral axis and cylindrical rhizomes of *Helosis guianensis* the vascular bundles are provided with a layer of sclerenchyma at the margin of the wood and bast. Further, in the cylindrical rhizomes of *Helosis,* the pith, situated internally to the vascular ring, consists entirely (*H. guianensis*), or at least in its peripheral portion (*H. mexicana*), of sclerenchymatous fibres, and the strips of ground-tissue, lying between the vascular bundles, also become sclerosed. The vessels of the Balanophoreae

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[1] The amount of balanophorin is so considerable that the shoots containing this substance are used as torches by the natives.

exhibit reticulate or striate thickenings; their perforations are simple in *Helosis* (E. Zimmermann). It is doubtful whether Eichler's statement (which is repeated by Engler) regarding the occurrence of scalariform perforations is correct. Tracheae with spiral thickenings, which can be unrolled, and annular vessels are said to be absent in this Order; mechanical elements are not developed in the xylem. The sieve-tubes of *Helosis* have scalariform sieve-plates at their ends and on the lateral walls (E. Zimmermann).

The **scale-leaves** of the Balanophoreae consist of homogeneous tissue, which includes groups of stone-cells in *Langsdorffia hypogaea* and *Lophophytum mirabile*. The number of the vascular bundles which pass into the scale-leaves and there undergo further branching, is three in *Langsdorffia hypogaea* and *Lophophytum mirabile*, and one in *Scybalium fungiforme*.

Literature: Unger, Kenntn. d. parasit. Pfl., Ann. Wiener Mus., Bd. ii, 1840, pp. 12–60.—Goeppert, Bau d. B. &c., Verh. kais. Leopold.-Karol. Akad. d. Naturf., Bd. xviii, Suppl. 1, 1841, p. 229 et seq. and 3 tab., and *Rhopalocnemis*, loc. cit., Bd. xxii, 1, 1847, p. 117 et seq. and Tab. xi–xv.—Poleck, Wachsähnl. Best. d. *Balanophora*, Verh. kais. Leopold.-Karolin. Akad., Bd. xxii, 1, 1847, p. 159 et seq.—Hooker, Struct. and aff. of B., Transact. Linn. Soc., vol. xxii, 1, 1855–6, p. 1 et seq. and pl. i–xvi.—Weddell, *Cynomorium coccineum*, etc., Arch. Mus. d'hist. nat., vol. x, 1858–61, pp. 269–308.—Chatin, Anat. comp. d. végét.: pl. parasit., pp. 93–101 and 105.—Solms-Laubach, Parasit. Phan., Pringsheim Jahrb., Bd. vi, 1867–8, pp. 529–39.—Eichler, *Lathrophytum*, Bot. Zeit. 1868, pp. 514–15, and B., in Martius Flor. brasil., vol. iv, 2, 1869, p. 1 et seq. and tab. ii, vi, viii, xii and xiii.—Beccari, in Nouv. Giorn. bot., vol. i, 1869, p. 65 et seq. and Tab. iii.—Solms-Laubach, Haustorium, Abh. naturf. Gesellsch. Halle, Bd. xiii, 1877, p. 267 et seq. and Tab. xxv.—De Bary, Vergl. Anat., 1877.—E. Zimmermann, *Helosis guianensis*, Flora 1886, pp. 371–86 and 400–2, Tab. vi.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1, 1889, pp. 244–7.—Peirce, Struct. of haustoria &c., Ann. of bot., vol. vii, 1893, p. 318 et seq.—[Pirotta e Longo, Stomi nel *Cynomorium*, R. Accad. dei Lienci 1899, pp. 98–100.]

EUPHORBIACEAE

(excl. Daphniphyllaceae and Buxaceae[1]).

1. Review of the Anatomical Features. No special anatomical features are common to all the Euphorbiaceae. On the other hand there are numerous anatomical characters, which may be of value in enabling one to recognize a plant as a member of this Order, and also for purposes of more precise determination.

In the structure of the leaf we may specially note that the stomatal apparatus is not of uniform structure. The pairs of guard-cells possess subsidiary cells of the type found in the Cruciferae or Rubiaceae, or they are surrounded by a number of ordinary epidermal cells. In the structure of the axis the following features may be mentioned. The cork in most cases develops subepidermally, rarely in a deeper cell-layer of the primary cortex, or in the epidermis. The pericycle either contains no sclerenchyma, or isolated bundles of bast-fibres, sometimes uniting to form a ring, or a composite sclerenchymatous ring, which is completely continuous or nearly so. Groups of bast-fibres are frequently present in the secondary bast, but only very rarely give rise to stratification of the latter. The primary and secondary bast-fibres are often characterized by a well-marked stratification of their walls. The xylem consists of: (*a*) medullary rays which are mostly narrow; (*b*) vessels, which either (in most cases) have simple perforations only, or both simple and scalariform, or (very rarely) exclusively scalariform perforations; in contact with parenchyma they either bear bordered pits only, or the latter are intermingled with simple pits of varying size; (*c*) wood-parenchyma, which is abundant in only a few members of the Order; (*d*) finally, wood-prosenchyma with thick walls and narrow lumina, or rather

[1] The Daphniphyllaceae and Buxaceae will be treated separately in an appendix at the end of the Euphorbiaceae.

thin walls and wider lumina ; in the former case the wood-prosenchyma is sometimes provided with a gelatinous layer, while in the second case it is septate ; in the majority of the Euphorbiaceae the walls of the wood-prosenchyma are furnished with simple pits, while in a small number of genera (of the Tribes Caletieae, Phyllantheae, Hippomaneae and Acalypheae) they bear bordered pits.

Oxalate of lime is mostly excreted in the form of ordinary solitary and clustered crystals; in certain species it is entirely absent. The following special forms of crystals are found: sphaerites (*Acalypha, Claoxylon, Croton, Crotonopsis, Eremocarpus, Gelonium*) ; styloids (*Bernardia, Colliguaya, Excoecaria, Pachystroma, Phyllanthus*) ; and rod-shaped crystals, bent like a V or W (*Phyllanthus*). In certain Ampereae, Crotoneae, Acalypheae and Hippomaneae clustered and solitary crystals occur in the epidermis of the leaf, while in many Euphorbiaceae they are found in special idioblasts in the mesophyll, the latter sometimes giving rise to transparent dots in the leaf. The internal secretory system is constituted as follows : I. laticiferous cells (in *Croton* pro parte, some Acalypheae, and many Hippomaneae and Euphorbieae) ; II. laticiferous vessels (in *Hevea* and *Manihot* only) ; III. rows of laticiferous sacs (only in *Micrandra*) ; IV. tanniniferous cells, sometimes differing from the surrounding cells in the size of their lumina or in their length, and occurring singly or in rows ; they are found principally in the bast, where they appear as more or less distinct idioblasts (widely distributed in all the Tribes) ; V. very much elongated secretory sacs, which frequently have wide lumina and are mostly filled with brown contents (in *Alchornea* (?), *Givotia, Mallotus, Pausandra, Pogonophora*) ; they must not be confounded with the laticiferous cells ; VI. secretory cells with oily or resinous contents (Fig. 180, *A–C*), which show varied differentiation, and have various shapes, and sometimes give rise to pellucid dots in the leaf (in *Ricinus* and the Eucrotoneae, excepting some species of *Croton* belonging to the section *Astraea*) ; VII. secretory lacunae, i.e. intercellular secretory spaces with curved epithelial cells loosely connected with one another ; they usually give rise to transparent dots in the leaf (in *Cluytia* and *Gelonium*) ; VIII. mucilage-cavities, or groups of mucilaginous cells (in certain Phyllantheae). Of all these secretory organs, only those numbered I–III have been shown to produce a milky juice.

The trichomes may be classified under clothing hairs, external glands, and stinging hairs (including the hairs containing clustered crystals). The usual form of the clothing hairs is the simple, unicellular or uniseriate trichome, which is frequently present. Special forms of such trichomes are the unicellular, two-armed hairs of *Argyrothamnia* and *Pausandra*, and the branched hairs of species of *Phyllanthus* and *Mabea*. The following types of clothing hairs (see Fig. 180) have a more complicated structure : stellate and tufted hairs (in the Ricinocarpeae, Phyllantheae, Crotoneae, Acalypheae and Hippomaneae) ; peltate hairs (in *Aextoxicon* and certain Phyllantheae, Crotoneae and Acalypheae) ; simple shaggy hairs (in certain Phyllantheae and Acalypheae) ; and candelabra-hairs (in species of *Croton*, Fig. 180, *K*). Regarding these hairs it may be added that sclerenchymatous cells belonging to the mesophyll are sometimes associated with the complicated trichomes of the species of *Croton* in such a way that they appear to form a component part of the hair ; some of the peltate hairs (Fig. 180, *L*) are provided with a small 'lower scale.' Ordinary glandular hairs are not common ; they have been observed in the tribes Ricinocarpeae, Phyllantheae, Acalypheae (here more frequent than elsewhere) and Hippomaneae. Large, variously shaped glands (Fig. 180, *M–O*), provided with a secretory palisade-like epidermis, are much more widely distributed; they occur on the petiole, on the surface of the leaf, on the leaf-teeth, or on the stipules of many species, and some of them are transitory. The genera *Cnesmone, Leptorhachis* and *Tragia*, belonging to the Acalypheae, and the genus *Dalechampia* have very characteristic

stinging hairs (Fig. 180, *P–Q*), the essential part of which is a cell containing a subulate crystal of oxalate of lime, suspended from beams of cellulose; *Jatropha* has stinging hairs showing the same structure as those of the nettle. Hairs or papillae with clustered crystals (Fig. 180, *R–S*), i.e. papillose projections of the epidermis, resembling stellate hairs or of spherical shape, and filled by a clustered crystal of oxalate of lime, are found in the genera *Acalypha*, *Argyrothamnia*, *Caperonia*, *Claoxylon*, *Fragariopsis* and *Plukenetia*, belonging to the Acalypheae.

Anomalous structural features are found in the axis of certain Euphorbiaceae; these consist in the occurrence of: I. intraxylary phloem (in *Croton* excl. species of the section *Astraea*, in *Crotonopsis*, *Eremocarpus* and *Julocroton*, of the Tribe Crotoneae; in *Alchornea*, *Conceveiba*, *Mallotus* pro parte and *Pera*, of the Tribe Acalypheae; in *Dactylostemon*, *Mabea*, *Senefeldera* and *Sebastiania* pro parte, of the Tribe Hippomaneae); II. secondary bundles of wood and bast in the parenchymatous pericycle in species of *Dalechampia* and *Fragariopsis*; III. interxylary phloem in *Dalechampia*; IV. medullary vascular bundles in *Ricinus*.

Finally, the following anatomical features are of minor systematic value: gelatinization of the epidermis of the leaf; papillose differentiation of the epidermis on the lower side of the leaf; development of hypoderm on the upper side of the leaf; cork-warts on the leaf (*Amanoa*); sclerenchymatous fibres and elongated spiral tracheids (*Pogonophora*) in the mesophyll; crystalloids and sphaero-crystals of undetermined nature, &c.

2. Structure of the Leaf. · The following description of the structure of the leaf and axis is mainly based on the various researches which have been carried out in Professor Radlkofer's botanical laboratory during the last few years[1]. The whole of the literature cited was also taken into account.

The anatomical features of the leaf are very varied; this is to be expected when the great extent of the Order is taken into consideration, and is well shown in the structure of the integumental tissue. The lateral walls of the epidermal cells may be either straight or undulated. The thickness of the outer walls varies, and is often considerable. In some cases the inner walls are strongly thickened, e.g. in some species of *Croton* (Frömbling), and also in some Hippomaneae (species of *Actinostemon*, *Givotia* and *Senefeldera*, according to Herbert). Rothdauscher

[1] In the description of the Euphorbiaceae I follow the classification of Müller Arg. in DC. Prodr., especially since the systematic-anatomical papers, referred to above, followed the same system of classification. It will therefore be appropriate to enumerate the ten Tribes of Müller's system, and at the same time to give an alphabetical list of the genera or species, which have been examined anatomically, in each Tribe: I. Caletieae: *Caletia hexandra*, Müll. Arg. and *Pseudanthus pimeleoides*, Spreng. were examined by me.—II. Ricinocarpeae: *Bertya gummifera*, Müll. Arg., *Beyeria viscosa*, Müll. Arg. and *Ricinocarpus pinifolius*, Desf. were examined by me.—III. Ampereae: I examined *Amperea spartioides*, Brongn.—IV. Phyllantheae: Frömbling and Rothdauscher examined species of the genera: *Actephila*, *Amanoa*, *Andrachne*, *Antidesma*, *Aporosa*, *Baccaurea*, *Bischoffia*, *Breynia*, *Cyclostemon*, *Discocarpus*, *Drypetes*, *Hemicyclia*, *Hieronyma*, *Hymenocardia*, *Lachnostylis*, *Melanthesopsis*, *Petalostigma*, *Phyllanthus*, *Putranjiva*, *Richeria*, *Sauropus*, *Savia*, *Securinega*.—V. Bridelieae: *Bridelia stipularis*, Bl. was examined by me.—VI. Crotoneae: Frömbling investigated species of the genera *Croton*, *Crotonopsis*, *Eremocarpus*, *Julocroton* and *Micrandra*.—VII. Acalypheae: Rittershausen examined species of the genera *Acalypha*, *Adriana*, *Agrostistachys*, *Alchornea*, *Aleurites*, *Argyrothamnia*, *Bernardia*, *Caperonia*, *Cephalocroton*, *Claoxylon*, *Cleidion*, *Cnesmone*, *Coccoceras*, *Coelodiscus*, *Conceveiba*, *Crozophora*, *Dysopsis*, *Fragariopsis*, *Hevea*, *Homonoya*, *Johannesia*, *Leptorhachis*, *Macaranga*, *Mallotus*, *Mercurialis*, *Pachystroma*, *Pera*, *Plukenetia*, *Ricinella*, *Ricinus*, *Sarcoclinium*, *Symphyllia*, *Tragia* and *Trewia*. VIII. Hippomaneae: Herbert investigated species of the genera *Acidocroton*, *Actinostemon*, *Adenocline*, *Adenopeltis*, *Carumbium*, *Chaetocarpus*, *Cluytia*, *Codiaeum*, *Colliguaya*, *Dactylostemon*, *Erismanthus*, *Excoecaria*, *Gelonium*, *Givotia*, *Hippomane*, *Hura*, *Jatropha*, *Mabea*, *Manihot*, *Maprounea*, *Microdesmis*, *Ostodes*, *Paradenocline*, *Pausandra*, *Pogonophora*, *Sebastiania*, *Senefeldera*, *Stillingia* and *Trigonostemon*.—IX. Dalechampieae: *Dalechampia* has been examined by Rittershausen.—X. Various Euphorbieae by several authors.

mentions a specially strong sclerotical differentiation of the outer wall of the epidermis as occurring on the lower side of the leaf in species of ***Amanoa*** and *Discocarpus*. According to the same author marginal pits are found in species of *Aporosa*, *Bischoffia*, *Cyclostemon*, *Drypetes* and *Hemicyclia*. Another noteworthy anatomical feature of the epidermis is its gelatinization, which is very extensive on the upper side of the leaf in the investigated species of the Caletieae. While the lower epidermis only includes isolated cells with mucilaginous inner walls, the corresponding walls of the upper epidermal cells coalesce to form a common mucilaginous layer. Amongst the Phyllantheae, Rothdauscher met with mucilaginous epidermal cells in certain species of *Actephila*, *Andrachne*, *Antidesma*, *Aporosa*, *Hieronyma*, *Hymenocardia*, *Richeria*, and *Securinega*, whilst Frömbling found them in species of *Petalostigma* and *Phyllanthus*; in the species examined by Rothdauscher, the mucilage-cells are occasionally of large size and spherical in shape; their lower ends penetrate into the mesophyll, and frequently only a small portion of the wall reaches the surface of the leaf. In the Crotoneae and Hippomaneae gelatinization of the epidermis of the leaf has not been observed, but it occurs in the Acalypheae (species of *Acalypha*, *Claoxylon*, *Homonoya*, *Leptorhachis*, *Pera* and *Tragia*, according to Rittershausen), and in the species of *Bridelia* (Tribe Bridelieae), examined by me. The nature of the markings on the cuticle is also very varied; of these we need only mention the occurrence of thick cuticular crests in species of *Mabea* (Herbert), and of very characteristic markings on the lower side of the leaf in *Aleurites*, *Hevea* and *Johannesia* (Rittershausen). According to Herbert, groups of silicified epidermal cells are found in species of *Actinostemon*, *Manihot*, *Pausandra*, *Sebastiania* and *Trigonostemon*; according to Rittershausen, rosettes of silicified cells containing cystolith-like bodies (like those of the Boragineae, but only silicified not calcified) occur in the epidermis of the leaf in the species of *Bernardia* in the immediate neighbourhood of the trichomes. Papillose development of the epidermis of the leaf is also very widely distributed. Amongst the Phyllantheae it has been observed on the lower side of the leaf in *Amanoa oblongifolia*, Müll. Arg., *Securinega Acidothamnus*, Müll. Arg. and *S. obovata*, Müll. Arg. by Rothdauscher, and in numerous species of *Phyllanthus*, and in *Melanthesopsis fruticosa*, Müll. Arg. by Frömbling. According to Rittershausen, a number of Acalypheae show the same feature, viz.: *Alchornea Martiana*, Müll. Arg., *A. Schomburgkii*, Klotzsch; *Conceveiba guianensis*, Aubl.; *Hevea discolor*, Müll. Arg.; *Homonoya riparia*, Lour.; *Johannesia princeps*, Vell. (only the subsidiary cells of the stomata); *Macaranga gummiflua*, Müll. Arg., *M. Helferi*, Müll. Arg., *M. javanica*, Müll. Arg. β *genuina* (in the neighbourhood of the glandular hairs), *M. indica*, Wight, *M. minutiflora*, Müll. Arg., *M. populifolia*, Müll. Arg., *M. tomentosa*, Wight; *Mallotus floribundus*, Müll. Arg.;—in *Macaranga triloba*, Müll. Arg., *Mallotus ricinoides*, Müll. Arg. and *Ricinus communis*, L. the epidermal cells on the upper side of the leaf are subpapillose. Finally, the lower epidermis of the leaf is entirely or partially papillose in some Hippomaneae, according to Herbert, namely: *Carumbium populneum*, Müll. Arg.; *Cluytia daphnoides*, Müll. Arg.; *Mabea angustifolia*, Benth. α *genuina*, *M. fistulifera*, Mart.; *Manihot coerulescens*, Müll. Arg. β *genuina*, *M. palmata*, Müll. Arg. α *diffusa*, *M. pilosa*, Pohl, *M. tripartita*, Müll. Arg. β *porrecta*, *M. utilissima*, Pohl; *Maprounea guianensis*, Aubl.; *Stillingia discolor*, Champ. et Benth., *S. nutans*, Vahl and *S. sebifera*, Michx. In *Euphorbia buxifolia*, Lam. the upper epidermis of the leaf is papillose (Warming). The shape of the papillae varies, e.g. capitate in *Maprounea guianensis*, in other cases frequently long and finger-shaped. Transitions from the latter type of papillae to simple, unicellular trichomes are sometimes found. Such transitional forms have been observed by Frömbling in *Phyllanthus praetervisus*, Müll. Arg. and by Herbert in *Sebastiania daphnoides*, Müll.

Arg. α *myrtilloides*. Another noteworthy feature is the occurrence of **hypoderm** on the upper side of the leaf. Amongst the Phyllantheae a single layer of hypoderm is found, according to Rothdauscher, in *Bischoffia javanica*, Bl., *Cyclostemon Cumingii*, Baill., *Hemicyclia andamanica*, Kurz, and locally also in *Hymenocardia acida*, Tul.; according to Frömbling, in *Phyllanthus indicus*, Müll. Arg., *P. obovatus*, Müll. Arg. and *P. puberus*, Müll. Arg., and locally also in certain other species of *Phyllanthus*. Rittershausen mentions the occurrence of a similar hypoderm in the following Acalypheae: *Agrostistachys indica*, Müll. Arg., *Aleurites moluccana*, Willd., *Pachystroma ilicifolium*, Müll. Arg.; amongst the Hippomaneae Herbert found a hypoderm in all the investigated species of *Gelonium* and in *Excoecaria Agallocha*, Müll. Arg. The occurrence of structures resembling cork-warts can be demonstrated on the lower side of the leaf in *Amanoa oblongifolia*, Müll. Arg. (Phyllantheae). Other special features of the integumental tissue, such as secretory cells (in *Ricinus*) and crystals (in representatives of the Ampereae, Crotoneae, Acalypheae and Hippomaneae) will be fully treated in the sections dealing with those subjects.

Concerning the **stomata**, we may first mention that in most of the Tribes (excluding the Crotoneae) they are usually confined to the lower side of the leaf, occurring more rarely on both surfaces. In the leaf of *Euphorbia buxifolia*, Lam., in which the lower half of the mesophyll is occupied by aqueous tissue, the stomata are found only on the upper side of the leaf (Warming). In very many Euphorbiaceae the stomatal apparatus belongs to the Rubiaceous type, the stomata being accompanied on either side by one or more subsidiary cells, which are placed parallel to the pore. In other cases, however, the Cruciferous type occurs, or the pairs of guard-cells may be surrounded by a relatively large number of cells, exhibiting no special arrangement. Regarding the special distribution of the Rubiaceous type, &c., amongst the Euphorbiaceae, the following facts may be mentioned. In the Ampereae (*Amperea*) the stomata are mostly surrounded by three epidermal cells. In the Phyllantheae (excl. Euphyllantheae) examined by Rothdauscher, the Rubiaceous type preponderates; *Andrachne*, *Aporosa*, *Baccaurea*, *Lachnostylis* and *Richeria* constitute the sole exceptions, the Cruciferous type being more or less distinct in these genera. In the Euphyllantheae Frömbling found no uniform type of stoma, for the cells adjacent to the guard-cells in this Tribe appear as subsidiary cells either of the Cruciferous or Rubiaceous types, both types often occurring side by side on the same leaf-surface. In the Acalypheae and Dalechampieae, according to Rittershausen, the Rubiaceous type is present in all cases, and the same (exception: *Manihot caerulescens*, Müll. Arg. β *genuina*) applies almost throughout the Hippomaneae, according to Herbert. In the Euphorbieae Benecke mentions the occurrence of the Rubiaceous type in *Mercurialis* and *Euphorbia*. It is impossible to enter into details here regarding the varied mode of insertion of the guard-cells, i.e. whether they are depressed, not depressed, or elevated. Only one noteworthy feature will be mentioned, that shown by the stomatal apparatus in *Caletia* and *Pseudanthus*, or, to be more precise, by the cells which adjoin the guard-cells and penetrate beneath them. The walls of these cells, which run at right angles to the surface of the leaf, and limit the outermost part of the respiratory cavity, appear, when examined in a superficial section, to be folded in a precisely similar manner to the well-known arm-palisade-cells (of Haberlandt) of the type with numerous arms. The object of this arrangement, which has also been observed in other Orders of plants, remains to be determined.

The **leaf-structure** may be either centric or bifacial; for details reference must be made to the special papers cited. I have met with rolled leaves having two furrows, one on either side of the median vein, and showing a corresponding type of structure, in the species of *Bertya* and *Ricinocarpus* mentioned above.

The following special features of the **mesophyll** are worth mentioning: the occurrence of a kind of arm-palisade-parenchyma in *Phyllanthus Roxburghii*, Müll. Arg.; the peculiar differentiation of the lowest cell-layer of the spongy tissue in *Microdesmis caseariaefolia*, Planch.; and the occurrence of sclerenchymatous elements running freely in the mesophyll, of spiral tracheids, and of enlarged terminal tracheids. In the species of *Microdesmis* mentioned above, the layer of cells referred to is strongly thickened on the side facing the interior of the leaf. Sclerenchymatous fibres, running freely in the leaf, are found chiefly in the Acalypheae, viz. according to Rittershausen in: *Acalypha diversifolia*, Müll. Arg. *α popoyaensis*; *Alchornea ilicifolia*, Müll. Arg., *A. latifolia*, Sw., *A. Martiana*, Müll. Arg. (according to loc. cit., p. 38), *A. Schomburgkii*, Klotzsch; *Bernardia axillaris*, Müll. Arg. *β genuina*, *B. celastrinea*, Müll. Arg., *B. gambosa*, Müll. Arg., *B. scabra*, Müll. Arg.; *Conceveiba guianensis*, Aubl., *C. trigonocarpa*, Müll. Arg.; *Mallotus Lawii*, Müll. Arg.; *Pera anisotricha*, Müll. Arg., *P. coccinea*, Müll. Arg., *P. distichophylla*, Baill., *P. heterodoxa*, Müll. Arg.; *Sarcoclinium longifolium*, Wight;—also according to the same author amongst the Dalechampieae in *Dalechampia affinis*, Müll. Arg., *D. brasiliensis*, Lam., *D. capensis*, Spreng. f., *D. caperonioides*, Müll. Arg., *D. ficifolia*, Lam., *D. Leandri*, Baill., *D. magnoliaefolia*, Müll. Arg., *D. scandens*, Müll. Arg. *β fallax*, *D. semitriloba*, Tausch, and *D. triphylla*, Müll. Arg. The same kind of sclerenchymatous fibres, frequently showing well-marked stratification of their walls, have also been observed by Herbert in the following Hippomaneae: *Actinostemon concolor*, Müll. Arg.; *Chaetocarpus castaneaecarpus*, Thw., *C. Pohlii*, Müll. Arg.; *Erismanthus obliquus*, Müll. Arg.; *Pausandra Morisiana*, Radlk.; *Sebastiania brasiliensis*, Müll. Arg., *S. multiramea*, Müll. Arg.; *Trigonostemon laurifolius*, Baill.;—and finally Rothdauscher met with them in *Actephila latifolia*, Benth. (Phyllantheae). Here we may mention the sclerenchymatous cells (rod-cells and sclerenchymatous fibres), which occur in connexion with the trichomes in many Crotoneae; they will be dealt with more fully in the description of the hairs. The spiral tracheids mentioned above occur only in the spongy tissue of *Pogonophora Schomburgkiana*, Miers; they have a tubular shape, are provided with a very delicate spiral band, and are about 40 μ in breadth. Herbert has shown that enlarged terminal tracheids occur in species of the genera *Givotia*, *Mabea*, *Sebastiania* and *Stillingia* (of the Hippomaneae). The special crystal-idioblasts of the mesophyll will be described in the section dealing with the crystalline elements.

In the structure of the **veins** we may first point out that the vascular bundles may or may not be accompanied by sclerenchymatous tissue. In some species of *Euphorbia* (*E. bahiensis*, Boiss. and *E. buxifolia*, Lam.) the bundles are surrounded by a parenchymatous sheath of large, wide cells (Warming). The smaller veins are either embedded or vertically transcurrent. In the following members of the Order the latter is the case: amongst the Phyllantheae the genera *Amanoa*, *Discocarpus*, *Hymenocardia*, *Lachnostylis*, *Richeria* and *Savia*, and some of the species of *Aporosa*, *Hemicyclia* and *Securinega*; amongst the Crotoneae some of the species of *Croton*; amongst the Acalypheae *Alchornea*, *Conceveiba*, *Macaranga*, *Mallotus*, *Trewia*, and *Bernardia celastrinea*, Müll. Arg., and *Hevea* (here vertically transcurrent on the upper side only); amongst the Hippomaneae *Hippomane* and species of *Manihot* and *Stillingia*.

Oxalate of lime is generally excreted in the form of clustered and solitary crystals. Both forms may occur side by side in the same plant; in other cases there are only clustered crystals, or (extremely rarely, in *Pachystroma*) only solitary crystals, or oxalate of lime may be entirely absent. The following special forms of crystals of oxalate of lime have been observed in this Order:

sphaerites, small rod-shaped crystals, often bent like a V or W, and styloids. Amongst the Crotoneae Frömbling met with sphaerites of oxalate of lime in the mesophyll in *Crotonopsis*, *Eremocarpus*, *Croton capitatus*, Müll. Arg. and *C. monanthogynus*, Michx.; of the Acalypheae *Acalypha* and *Claoxylon* likewise possesses sphaerites, which lie in hemispherical, projecting epidermal cells of the axis and leaf (Rittershausen); lastly, they are also found in the pith of *Gelonium*, according to Herbert. The small rod-shaped crystals, which are bent like a V or W, and recall the analogous forms of crystals found in the Papilionaceae, have only been observed in the mesophyll of some species of *Phyllanthus*. Typically differentiated styloids are found in the bast in species of *Phyllanthus*, in the leaf and axis in *Pachystroma*, and in the bast of *Bernardia*; styloids, showing less typical differentiation, occur in the bast in *Colliguaya* and *Excoecaria*. The terminal cells of the stinging-hairs of *Cnesmone*, *Dalechampia*, *Leptorhachis* and *Tragia* contain crystals resembling styloids; further details will be given below. The ordinary crystalline elements of oxalate of lime, especially the clustered crystals, more rarely the solitary crystals, are contained in special idioblasts, in certain members of the Order; these idioblasts are distinguished either by their large or small size, sometimes also by their shape. Very frequently they are found in the epidermis of the leaf, either singly or arranged in small groups, and they are often characterized by their small size and their rounded outline in surface-view.

Amongst the Ampereae I met with roundish crystal-idioblasts in both the upper and lower epidermis of *Amperea spartioides*, Brongn.; the clustered crystals, which they contain, are embedded in a thickening of the inner wall. Amongst the Crotoneae clustered crystals in the epidermis of the leaf have only been observed in *Julocroton triqueter*, Müll. Arg. On the other hand they are present in many Acalypheae and Hippomaneae. Amongst the Acalypheae *Agrostistachys*, *Aleurites*, *Cleidion*, *Coelodiscus*, *Conceveiba* pro parte, *Homonoya* and *Trewia* possess idioblasts, which contain clustered crystals, but otherwise differ little from the rest of the epidermal cells; in *Acalypha* pro parte, *Alchornea*, *Claoxylon*, *Dalechampia* and *Mallotus* the epidermal cells containing the clustered crystals are of considerable size, and consequently penetrate into the mesophyll; the idioblasts of *Argyrothamnia* and *Caperonia*, which also contain clustered crystals, are distinguished by having a smaller, roundish lumen, and by being arranged in small groups. In some other Acalypheae, the idioblasts, containing clustered crystals, project like papillae or hairs, but these will be dealt with in the description of the hairy covering. Amongst the Acalypheae solitary crystals in the epidermis of the leaf have hitherto only been observed in *Cnesmone javanica*, Bl. and in *Dalechampia scandens*, Müll. Arg. β *fallax*. Amongst the Hippomaneae small idioblasts, containing clustered crystals, have been shown to occur in the epidermis of the leaf in species of *Hippomane*, *Manihot*, *Ostodes* and *Pausandra*. Herbert, who investigated this Tribe, was not able in all cases to determine with certainty whether the large crystal-idioblasts, which occur in other Hippomaneae, belong exclusively to the palisade-tissue or are epidermal cells depressed to the level of the palisade; these idioblasts either contain clustered crystals (*Acidocroton*, *Jatropha* pro parte, *Givotia*) or solitary crystals (*Erismanthus*, *Microdesmis*, *Pogonophora*, *Stillingia* pro parte), the latter being frequently inserted in a thickening of the inner wall.

Large crystal-idioblasts, which for the most part have a suberized wall, and are occupied by clustered or solitary crystals, are equally common in the mesophyll, and sometimes give rise to transparent dots in the leaf [1].

The mesophyll in all the investigated Crotoneae (Frömbling) contains large crystal-idioblasts with suberized walls; in the majority of the Crotoneae large

[1] Transparent dots in the leaf in the Euphorbiaceae are also caused by secretory cells and lacunae (see below), and, in certain species of *Excoecaria* and *Euphorbia*, by special features of the mesophyll, viz. respiratory cavities on the upper side of the leaf, and the meshes in the network of veins (Radlkofer).

clustered crystals are found in these elements, while in *Crotonopsis*, *Eremocarpus*, *Croton capitatus*, Müll. Arg. and *C. monanthogynus*, Michx. the latter contain the sphaerites mentioned above. In the Acalypheae also, as far as can be gathered from Rittershausen's statements, this feature is not rare, being found for example in *Ricinella*, in which Radlkofer first pointed out the pellucid dots caused by the clustered crystals. According to my own observation I may add that large sacs, filled with solitary crystals, are present in the palisade-parenchyma of *Bridelia stipularis*, Bl. (Tribe Bridelicae).

A third special feature presented by the crystalline elements in the leaf is the occurrence of small clustered crystals in chambered cells of the palisade-tissue; this feature is recorded by Rittershausen in species of *Alchornea*, *Cephalocroton* and *Hevea*.

Having dealt with the oxalate of lime we may add a few words on the occurrence of crystalloids, crystals of abietinic acid, sphaerites in alcohol material of *Euphorbias*, and fatty bodies. Crystalloids have been observed by Fry in the stem of *Euphorbia splendens*, where they occur in the inner cell-layers of the primary cortex, and also in the leaf (mainly in the mesophyll above the vascular bundles of the veins); beautiful crystalloids are also found in the latex of *Jatropha* (see p. 747). Pax mentions the occurrence of crystals having the shape of a whetstone and consisting of abietinic acid in the cortical tissue of *Euphorbia splendens*. Sphaerites are met with in alcohol material in the tissues of the Cactus-like *Euphorbias*, e.g. *E. Caput Medusae*, and have been investigated by various authors (Leitgeb, Rodier, Schaarschmidt, Hansen and Belzung). To judge from a microchemical examination carried out by Hansen, they consist of calcium phosphate, but according to a macrochemical investigation by Belzung, they are composed partly of calcium malophosphate, and partly of calcium malate. Fatty bodies are present in the mesophyll in many members of the Order.

The **secretory elements** of the Euphorbiaceae require a detailed description, especially as some of them were not quite correctly [1] interpreted by Pax (in Engler, Bot. Jahrb. 1884, and Natürl. Pflanzenfam.). The following types of secretory elements are found in the Euphorbiaceae, and will be described in order: I. Laticiferous cells; II. Laticiferous vessels; III. Rows of laticiferous sacs; IV. Tannin-sacs and rows of tannin-cells ('gegliederte Milchsaftröhren' and 'gegliederte Milchsaftschläuche' of Pax); V. Elongated secretory sacs with wide lumina, and usually with brown contents; VI. Secretory cells; VII. Secretory lacunae; VIII. Mucilage-lacunae.

I. The **laticiferous cells** are confined to the tribes Crotoneae, Acalypheae, Hippomaneae and Euphorbieae. Amongst the Crotoneae they are only found in some of the species of *Croton* [2] (Frömbling); in the tribe Acalypheae only

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[1] It would be out of place here to enter into a detailed criticism of Pax's statements; two points only may be shortly referred to. The elements described by Pax as laticiferous vessels ('gegliederte Milchröhren') or articulated sacs ('gegliederte Schläuche') do not correspond to what are called laticiferous vessels ('gegliederte Milchröhren') in the plant-anatomy of the present day, but are only rows of cells with distinct transverse walls and special contents (mostly brown and tanniniferous); moreover the laticiferous nature of these contents in the living plant has not yet been proved either by Pax or by other observers. In the second place the following statement on p. 5 in the Natürl. Pflanzenfamilien is only partially correct: 'häufig werden die Querwände resorbiert und die Milchröhren nehmem in hohem Grade das Aussehen ungegliederter Schläuche an, so bei den Jatropheae, Manihoteae und Crotoneae.' This is shown by the fact that laticiferous vessels are only known in *Hevea* and *Manihot*, while *Jatropha*, *Croton*, &c., possess true laticiferous cells.—Similarly in view of the wide distribution and general use of Möller's book on the anatomy of the cortex it seems advisable to refer to the partly incorrect terminology of the secretory organs in the Euphorbiaceae employed in this book also. The laticiferous cells are termed laticiferous canals in the bast of *Andira brasiliensis* (= *Johannesia princeps*), secretory sacs in the cortex of *Jatropha Curcas*, and laticiferous sacs in the bast of *Baloghia lucida* (= *Codiaeum lucidum*).

[2] Namely *Croton adenophyllus*, Spreng., *C. agrarius*, Müll. Arg., *C. argyranthemus*, Michx., *C. Cajucara*, Benth., *C. Cascarilla*, Benn., *C. celtidifolius*, Baill., *C. chrysocladus*, Müll. Arg.,

in the genera *Aleurites, Johannesia, Macaranga* and *Pachystroma* (but according to my own observations not in *Alchornea* and *Mallotus*, where they are stated to occur by Rittershausen); in the Tribe Hippomaneae in the genera *Actinostemon, Adenocline, Adenopeltis, Codiaeum, Colliguaya, Dactylostemon, Excoecaria, Hippomane, Hura, Jatropha, Mabea, Maprounea, Ostodes, Paradenocline, Sebastiania, Senefeldera, Stillingia* and *Trigonostemon* (Herbert). In the Tribe Euphorbieae the distribution of the laticiferous cells has been little investigated, and hitherto these elements have only been demonstrated in *Euphorbia*, in *Mercurialis* and *Ricinus* (Hanstein), and *Poinsettia* (Pirotta and Marcatili). Regarding their course of development, Hanstein and Chauveaud have shown that they are differentiated at a very early stage in the plane of the cotyledonary node, their initial cells being situated in the outermost cell-layer of the central cylinder; the initial cells either compose the whole of this layer, or they are arranged in it in the form of four arcs; in *Croton* a second ring of initial cells is found in the middle of the primary cortex. The course of the laticiferous tubes in the mature plant is as follows: in the axis they occur in the pith [1], bast, and primary cortex, whilst in the leaf they are found in the veins and sometimes [2] also free in the mesophyll. The laticiferous tubes, which run freely in the mesophyll, sometimes exhibit a very striking relation to the assimilatory system (Haberlandt), and not uncommonly extend as far as the epidermis of the leaf. The wall of the laticiferous tubes is sometimes (e.g. in the fleshy *Euphorbias*) exceptionally thick, and is often provided with large pits. The thick transverse walls, observed by De Bary and Dippel in the older laticiferous tubes of *Euphorbia Lathyris*, appear to be secondary formations. The contents are generally milky in the living plant; in herbarium-material they have a brown or grey colour. Dietz has shown that a number of crystallizable organic substances are present in the coagulated latex of the *Euphorbias*; the latex also frequently contains tannin. Treub found nuclei in the laticiferous tubes of the *Euphorbias*. The following special substances are found in the contents of the laticiferous tubes: clustered crystals of oxalate of lime (in *Hura* and *Mabea*, according to Herbert); crystalloids having the form of tetragonal flakes with rounded corners (in *Jatropha*, according to Trécul and Herbert); finally, rod- or bone-shaped starch-grains (in *Euphorbia splendens* and other species, and also in *Hura crepitans*, Müll. Arg.).

C. ciliato-glandulosus, Ortega, *C. comosus*, Müll. Arg., *C. Cortesianus*, H. B. K., *C. discolor*, Willd., *C. exuberans*, Müll. Arg., *C. flavens*, Müll. Arg., *C. Frionis*, Müll. Arg., *C. fruticulosus*, Müll. Arg., *C. gracilipes*, Baill., *C. humilis*, L., *C. incertus*, Müll. Arg., *C. Klotzschii*, Müll. Arg., *C. lachnocladus*, Mart., *C. linearifolius*, Müll. Arg., *C. linearis*, Jacq., *C. lobatus*, Müll. Arg., *C. Lundianus*, Müll. Arg., *C. morifolius*, Müll. Arg., *C. origanifolius*, Müll. Arg., *C. pallidus*, Müll. Arg., *C. panamensis*, Müll. Arg., *C. paraënsis*, Müll. Arg., *C. paulinus*, Müll. Arg., *C. pedicellatus*, H. B. K., *C. Pohlianus*, Müll. Arg., *C. pulegiodorus*, Baill., *C. pungens*, Müll. Arg., *C. rhamnifolius*, Müll. Arg., *C. Sagraeanus*, Müll. Arg., *C. sclerocalyx*, Müll. Arg., *C. semivestitus*, Müll. Arg., *C. Soliman*, Cham. et Schlecht., *C. stipulaceus*, H. B. K., *C. subacutus*, Müll. Arg., *C. subvillosus*, Müll. Arg., *C. tridentatus*, Mart., *C. Urucurana*, Baill., *C. Vauthierianus*, Baill., *C. vepretorum*, Müll. Arg., *C. Wilsonii*, Griseb., *C. xalapensis*, H. B. K.

[1] The laticiferous cells are never found solely in the pith. Rittershausen's statements regarding their occurring exclusively in the pith in *Alchornea, Aleurites* and *Mallotus* require correction, as shown by the following data: firstly, in *Alchornea* (according to my own examination of *A. cordata*, Müll. Arg.) laticiferous tubes are not present—elongated secretory sacs may possibly be present in some of the species examined by Rittershausen, and, if so, were incorrectly interpreted by him; secondly, the laticiferous cells of *Aleurites* (*A. moluccana*, Willd.) occur not only in the pith, but also in the bast and primary cortex; and thirdly, the laticiferous cells, mentioned by Rittershausen as occurring in the pith of *Mallotus*, are really secretory sacs (see under V) according to my own examination of *M. oreophilus*, Müll. Arg.

[2] According to Rittershausen, amongst the Acalypheae in *Pachystroma* only; according to Frömbling, in almost all species of *Croton*; according to Herbert, quite generally in the Hippomaneae; according to Marcatili and Pirotta, in *Euphorbia* and *Poinsettia* (cf. also Haberlandt, Groom and Scott, ll. cc.).

II. The **laticiferous vessels** are only found in two genera, viz. *Hevea* (well-known caoutchouc-plants) and *Manihot*, where they were first observed by Scott, Calvert and Boodle. They occur chiefly in the bast of the vascular

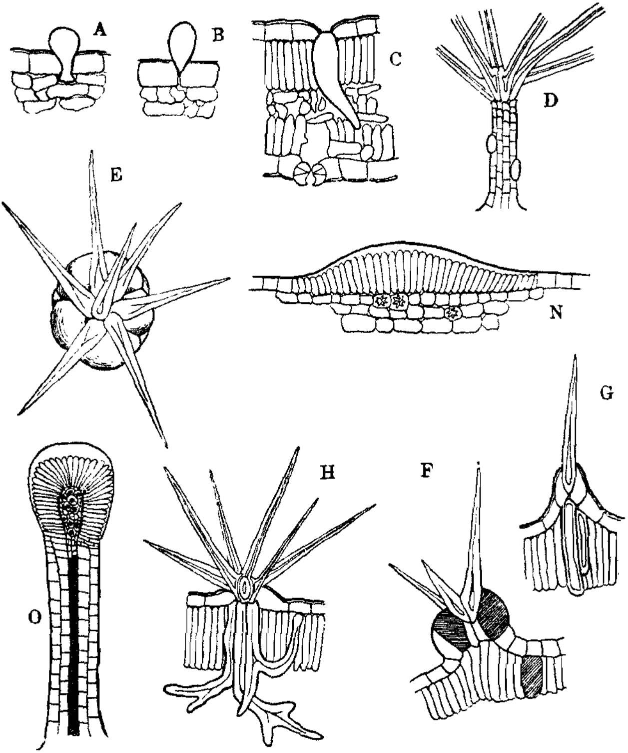

FIG. 180 (a). A, Crateriform secretory cell of *Croton monanthogynus*, Michx. B, Pyriform secretory cell of *Julocroton fuscescens*, Baill. C, Secretory cell in the leaf of *Croton eremophilus*, Müll. Arg. D–F, Stellate or tufted hairs with secretory cells at their base: D, *Croton subacutus*, Müll. Arg.; E–F, *C. pulegiodorus*, Baill. G–L, Various trichomes: G, *C. exuberans*, Müll. Arg.; H, *C. agoensis*, Baill.; I, *Julocroton fuscescens*, Baill.; K, *Croton discolor*, W.; L, *C. floribundus*, Spreng. M, Patelliform gland of *C. glandulosus*, Müll. Arg., section. N, Glandular margin of the leaf of *C. refractus*, Müll. Arg. in section. O, Morulose gland of *C. ciliato-glandulosus*, Ort. P–Q, Stinging hairs of *Tragia cissoides*, Müll. Arg. R–S, Hairs containing clustered crystals, from *Plukenetia*.—A–D, G–H and M–O after Frömbling, E–F, I–K and P–Q Original, L after Bachmann, R–S after Rittershausen.

bundles in the axis and leaf; but they have also been met with in the primary cortex in *Hevea* (Rittershausen), and at the margin of the pith and in the

primary cortex in *Manihot*. In the living plant their contents are milky in *Hevea*, of the nature of a watery sap in *Manihot*. Nuclei have been demonstrated in the laticiferous tubes of *Manihot*.

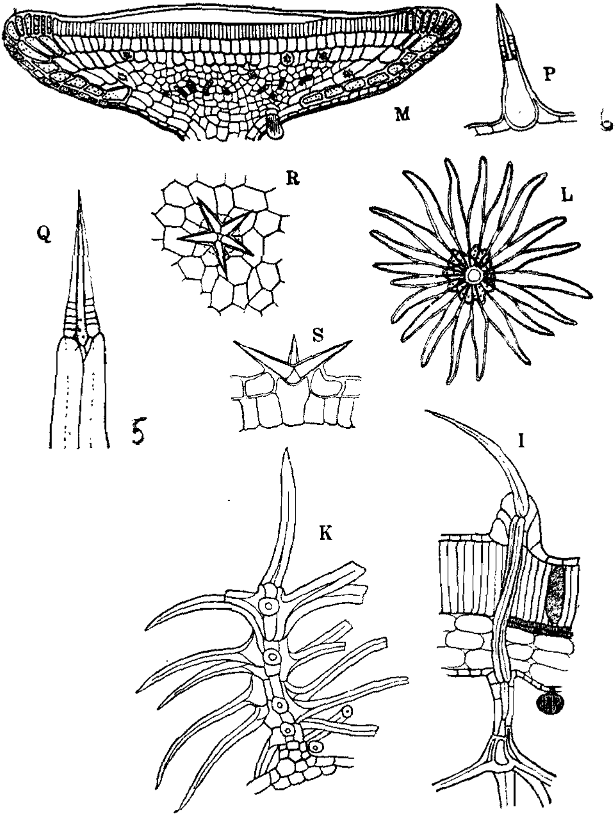

FIG. 180 (*b*).

III. The rows of laticiferous sacs are confined to the genus *Micrandra* (Frömbling). The cells forming these rows have rather wide lumina, show various degrees of elongation, and in herbarium-material are filled with granular

contents having a grey colour. In the axis, they are present in the pith, bast, and primary cortex, while in the leaf they run independently of the veins, being free in the mesophyll, where they form long chains of cells. The expression 'rows of laticiferous sacs' is justified by the fact that the species of *Micrandra* are described as trees with latex, and that other secretory organs are not present.

IV. Elements very widely distributed in almost all the Tribes are **cells** filled with brown, **tanniniferous** contents (in herbarium material); these elements are often distinguished from the adjoining cells by the size of their lumina, or by their greater elongation, and either occur singly or united in groups; they are chiefly found in the bast, but are also present in the pith and primary cortex of the branch. Pax terms these elements articulated sacs (gegliederte Schläuche), articulated laticiferous sacs (gegliederte Milchsaftschläuche), or even (inadmissibly) articulated laticiferous tubes (gegliederte Milchsaftröhren), and ascribes great systematic importance to them for the subdivision of the Euphorbiaceae according to his scheme of classification. According to more recent observers, and my own views also, Pax has certainly gone too far in this respect. The elements in question are frequently connected with ordinary tanniniferous cells by transitional forms, so that it is often difficult to decide whether the tanniniferous cells of a given plant should be regarded as Pax's elements or not. The contents of these elements, at any rate in herbarium-material, give no more assistance than does their shape towards making a clear diagnosis; moreover not a single case has hitherto been recorded in which the contents have proved to be characteristic and of the nature of latex, in the living plant.

V. The fifth kind of **secretory** organ is formed by elongated **sacs**, which mostly have wide lumina, and are generally filled with brown contents in herbarium-material. They are often very long, and are then easily confounded with laticiferous cells, unless their development is investigated, especially as the laticiferous cells often possess similar brown contents. In order that such mistakes may be avoided, it may be noted that the secretory sacs usually occur solely in the pith, while this is never the case with the laticiferous cells, and that they generally have a larger diameter (reaching 95 μ) than the latter. In some cases (*Mallotus oreophilus*, Müll. Arg.) the secretory sacs in a transverse section of the branch are surrounded by a ring of cells, having small lumina and resembling an epithelium. They occur in the pith, and sometimes also in the bast, pericycle, and primary cortex. They have been observed in species of *Mallotus* and *Alchornea* (Tribe Acalypheae), and species of *Givotia*, *Pausandra* and *Pogonophora* (Tribe Hippomaneae, according to Herbert).

VI. **Secretory cells**, viz. idioblasts with oily or resinous contents, are only known to occur in *Ricinus*, and in the genera *Croton*, *Julocroton*, *Crotonopsis* and *Eremocarpus* of the Crotoneae, that is to say in all the Eucrotoneae (with the exception of a few species of *Croton*, belonging to the section *Astraea*). In the Eucrotoneae they frequently give rise to transparent dots in the leaf. The secretory cells of *Ricinus communis*, L. are large cells present in the epidermis on both sides of the leaf, and penetrating somewhat into the mesophyll, whilst only a small portion of the wall of these cells reaches the surface of the leaf; they are more commonly met with on the under side of the lamina, where they usually have an elongated shape; they contain a secretion, which is yellowish-brown in the dried plant, but bright and strongly refractive in the living plant. The following statements may be made regarding the secretory cells of the Eucrotoneae. They are absent in only a few species of *Croton* belonging to the section *Astraea* (*C. comosus*, Müll. Arg., *C. Klotzschii*, Müll. Arg., *C. lobatus*, Müll. Arg. and *C. paulinus*, Müll. Arg.); a further peculiarity of these species is the absence of the intraxylary soft bast characteristic of the

Eucrotoneae, and for these reasons they should probably be excluded from the latter Tribe. In herbarium-material the secretory cells of the Eucrotoneae have bright-yellow translucent, oily contents readily soluble in alcohol and ether; their walls are suberized; in many cases they emit an aromatic scent, which is usually agreeable, and is recognizable even in herbarium-material. They are found both in the leaf and axis. In the axis, they occur in the epidermis, pith and primary cortex, and also in the bast; in the first three tissues they are mostly spherical in shape, while the secretory cells in the phloem are elongated and tubular. In the leaf, they are found in the epidermis and mesophyll. In the latter tissue they have a spherical or long oval shape, according as they belong to the spongy or palisade-tissue. The epidermal secretory cells vary greatly in shape, and according to Frömbling the following forms may be distinguished: (1) secretory cells, situated on a level with the epidermis, and only distinguished from the rest of the epidermal cells by their spherical shape and their contents; (2) secretory cells projecting above the epidermis as papillae, but again possessing a completely spherical shape; (3) papillose secretory cells, projecting more strongly, and either crateriform (Fig. 180, *A*) or pyriform (Fig. 180, *B*); (4) depressed secretory cells, lying on a lower level than the remaining epidermal cells; only a small portion of the wall of these elements reaches the surface of the leaf, and thus limits part of the pit-like depression situated above the secretory cell; the latter has a spherical or long tubular shape and penetrates into the mesophyll (Fig. 180, *C*). Regarding the distribution of the secretory cells in the tissues of the leaf, the following points remain to be mentioned. The secretory cells are found in the epidermis of the leaf [1] in all species. They are never restricted to the upper epidermis, for when present there they are also found in the lower epidermis. They are of rare occurrence in the mesophyll (*Croton amabilis*, Müll. Arg., *C. compressus*, Lam., *C. corylifolius*, Lam., *C. gratissimus*, Burch., *C. hemiargyreus*, Müll. Arg., *C. Mubango*, Müll. Arg. and *C. reticulatus*, Müll. Arg., and also *Julocroton fuscescens*, Baill.). A specially noteworthy feature is the presence of secretory cells in the epidermis of the pedestals of the stellate and tufted hairs (Fig. 180, *D–F*). It is impossible to establish a definite rule regarding the distribution of the various forms of epidermal secretory cells, since different types are frequently present side by side in the same plant. According to Frömbling, however, tubular secretory cells traversing the entire thickness of the leaf, and those of crateriform shape, appear to be characteristic of definite groups of species; this is seen to be the case if the list of species [2] enumerated for this purpose in the foot-note below be compared with the classification given by Müller Arg. It may be added that the crateriform secretory cells are in most cases (exception *Croton astroites*, Müll. Arg.) found only on the

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[1] Frömbling's statement (on p. 49 of his treatise) that in *Croton reticulatus* secretory cells occur only in the spongy tissue is a mistake, which may be corrected here.

[2] The following species possess crateriform secretory cells: *Croton agoensis*, Baill., *C. amabilis*, Müll. Arg., *C. astroites*, Müll. Arg., *C. betulinus*, Vahl, *C. buxifolius*, Müll. Arg., *C. capitatus*, Müll. Arg., *C. Catinganus*, Müll. Arg., *C. ceanothifolius*, Baill., *C. cneorifolius*, Müll. Arg., *C. compressus*, Lam., *C. Corchoropsis*, Baill., *C. floribundus*, Spreng., *C. Gaudichaudi*, Baill., *C. gratissimus*, Burch., *C. hemiargyreus*, Müll. Arg., *C. longinervius*, Müll. Arg., *C. maritimus*, Walt., *C. micans*, Müll. Arg., *C. migrans*, Casar., *C. Mubango*, Müll. Arg., *C. Palanostigma*, Klotzsch, *C. tenellus*, Müll. Arg., *C. verbenaefolius*, Müll. Arg., *C. Widgrenianus*, Müll. Arg.; *Julocroton argenteus*, Fr. Didrichs., *J. fuscescens*, Baill., *J. stipularis*, Müll. Arg., *J. triqueter*, Müll. Arg.; *Eremocarpus setigerus*, Benth. Elongated secretory cells, which traverse a portion, or often the whole of the mesophyll, have been observed in *Croton Benthamianus*, Müll. Arg., *C. Betulaster*, Müll. Arg., *C. cerino-dentatus*, Müll. Arg., *C. dichotomus*, Müll. Arg., *C. eremophilus*, Müll. Arg., *C. glutinosus*, Müll. Arg., *C. grewiaefolius*, Müll. Arg., *C. Hjalmarsonii*, Griseb., *C. lucidus*, L., *C. Lundianus*, Müll. Arg., *C. matourensis*, Müll. Arg., *C. muscicapa*, Müll. Arg., *C. oxyphyllus*, Müll. Arg., *C. sclerocalyx*, Müll. Arg., *C. sincorensis*, Mart., *C. timandroides*, Müll. Arg., *C. virgultosus*, Müll. Arg.

lower side of the leaf, and only in species the leaves of which bear a dense hairy covering. Regarding the general distribution of the forms of secretory cells described above amongst the genera of the Eucrotoneae, the following statements may be taken from Frömbling's work. In *Croton* all the different types occur, viz. secretory cells in the mesophyll (in a few of the species, see above), and the various forms of secretory cells found in the epidermis; in *Julocroton* there are secretory cells in the mesophyll (*Julocroton fuscescens*, Baill.), and those of crateriform shape in the epidermis; in *Crotonopsis* the second and fourth types of epidermal secretory cells are present; finally in *Eremocarpus*, crateriform secretory cells only.

VII. The **secretory lacunae**, observed by Herbert in almost all species of the two genera *Cluytia* and *Gelonium* (exception: *Cluytia alaternoides*, Müll. Arg.) belonging to the Hippomaneae, are unique; they frequently give rise to well-marked transparent dots in the leaf, and their structure recalls that of the intercellular secretory receptacles of *Derris*, *Lonchocarpus* and other Leguminosae. The spongy tissue of the two genera mentioned above contains rather large intercellular spaces, filled with a colourless, or yellow, or brown secretion, and surrounded by secretory cells, which for the most part have a serpentine form. Closed intercellular secretory spaces, provided with an epithelium, have not been observed.

VIII. **Mucilage-lacunae**, or rather groups of cells with mucilaginous walls, were first met with by Vesque in the primary cortex of *Bischoffia javanica*, and subsequently by Rothdauscher in other Phyllantheae also (viz. species of *Antidesma*, *Baccaurea*, *Hieronyma*, *Hymenocardia* and *Securinega*), and by Rittershausen in *Adriana* (Acalypheae).

Having described the secretory organs, we may now deal with the trichomes, which may be divided into three groups: I. Clothing hairs; II. External glands; III. Stinging hairs (including the hairs containing clustered crystals).

I. The **clothing hairs** include a large number of forms. In the simplest case they are unbranched unicellular or uniseriate structures. A type of clothing hairs found by Rothdauscher in the Phyllantheae consisted of simple and unicellular or septate hairs, the latter being divided by a few walls; according to my own investigation *Bridelia stipularis*, Bl. (Tribe Bridelieae) possesses uniseriate trichomes; the Crotoneae, according to Frömbling, have unicellular hairs, but (excepting species of *Croton* belonging to the section *Astraea*) these hairs never occur alone, but are always accompanied by other more complicated trichomes (stellate and tufted hairs); according to Rittershausen both forms of hairs are widely distributed in the Acalypheae, whilst unicellular trichomes are present in *Dalechampia* (Tribe Dalechampieae); finally Herbert also mentions simple unicellular, or rarely uniseriate trichomes as occurring in the Hippomaneae. The following special forms of the simple clothing hairs are noteworthy: (*a*) unicellular two-armed trichomes, which have thick or thin walls, and have narrow lumina in the former, and wider lumina in the latter case; they occur in the genus *Argyrothamnia* (Acalypheae), and in the genus *Pausandra* (Hippomaneae); (*b*) the trichomes of *Sarcoclinium*, which are quite short, and have rather wide lumina and thick walls, and the trichomes of *Coelodiscus*, which are likewise very short and have thick walls, and are mostly bent like a hook at the apex; lastly (*c*) the branched multicellular trichomes found in *Phyllanthus reticulatus*, Müll. Arg., and in the genus *Mabea* (Hippomaneae). The trichomes of *Phyllanthus reticulatus* are dichotomously branched, the axis and branches consisting of a row of thin-walled cells. The branched hairs of the species of *Mabea* are shaped like antlers; the main axis and its branches are formed by a row of cells, which have thick walls and narrow lumina, the terminal cells of the branches being provided with narrow lateral protrusions, an indication of branches of the second order. The following

types of clothing hairs exhibiting a more complicated structure are found in this Order: (*a*) tufted and stellate hairs with transitions to peltate hairs (the former in the Ricinocarpeae, Phyllantheae, Crotoneae, Acalypheae and Hippomaneae, the latter in certain representatives of the Phyllantheae, Crotoneae, Acalypheae and in the doubtful genus *Aextoxicon*, which is referred to the Euphorbiaceae by Bentham and Hooker); (*b*) simple shaggy hairs, i.e. bi- or multiseriate trichomes (in representatives of the Phyllantheae and Acalypheae); and (*c*) candelabra-hairs with a multiseriate main axis (in *Croton*, Fig. 180, *K*). We may add that the stellate, tufted and peltate hairs are often seated on multiseriate stalks of varying length.

In the following paragraphs the more complicated trichomes will be described in detail under the individual Tribes. Amongst the Ricinocarpeae, I have observed tufted hairs in *Ricinocarpus*, *Beyeria* and *Bertya*, where they fill the furrows of the rolled leaves. The ray-cells in this case are either sunk in the epidermis of the leaf or are seated on a short, multiseriate stalk. Stellate hairs are also mentioned by systematists as occurring in the genus *Beyeriopsis*, which belongs to the same Tribe.

In the Phyllantheae, clothing hairs of complicated structure are not common. According to Rothdauscher, *Andrachne aspera*, Spreng. possesses uniseriate trichomes with a short, almost spherical, though apparently not secretory, terminal cell, and, accompanying these, similarly constructed shaggy hairs, which are biseriate at the base, but either become uniseriate above, and terminate in a spherical cell, or fork into two uniseriate branches, each of these having a spherical terminal cell. Peltate hairs occur in the genus *Hieronyma*; the shield is composed of a large number (up to 36) of thick-walled ray-cells, which bend downwards near the centre of the shield, and thus form the stalk, the latter being sunk in the epidermis; the peltate hairs of the genus *Hymenocardia* (which is likewise described as scaly) are bladder-like and glandular, and will be described in greater detail amongst the external glands. Stellate or tufted hairs appear to be very rare among the Phyllantheae; the only record I am aware of is a statement made by Müller Arg. in DC. Prodr. on the rare occurrence of stellate hairs in the genus *Baccaurea*.

In the Crotoneae, the third Tribe to be considered, the forms of the trichomes are very varied. Typical simple hairs are extremely rare in this Tribe, as remarked above, and where they occur, they mostly appear as rudimentary forms of more complicated trichomes (Fig. 180, *G*). Frömbling, whose description I follow here, divides the trichomes having a more complicated structure into two groups: (*a*) hairs with a distinctly developed central cell; and (*b*) hairs without a central cell, or those in which a central cell, though originally present, is not recognizable in the mature condition. In those hairs, which have a distinctly developed central cell, the latter is either not specially prominent, or forms a 'central ray' of variable length and structure. The hairs with a central cell belong either to the peltate or stellate type; amongst the latter Frömbling only includes those trichomes in which the rays run in a flat or funnel-shaped plane, and are only connected with one another basally. Numerous transitions are to be found between the stellate and peltate hairs. The stalk of the trichomes in question is short or of some little length, and consists of several rows of cells; not uncommonly the component cells are suberized at a certain level throughout the whole thickness of the stalk. According to O. Bachmann and Radlkofer the occurrence of a small lower scale is specially characteristic of the peltate hairs (Fig. 180, *L*) and of the forms of stellate hairs most nearly related to them; below the actual shield in these cases one finds a second central layer of smaller cells, which are mostly provided with large pits. The composite trichomes with no central cell are divided by Frömbling into: (*a*) tufted hairs, in which the ray-cells are directed upwards, and are usually sunk in the epidermis, or are attached to a more or less elevated portion of the latter, i.e. to a kind of pedestal; (*b*) stalked star-shaped hairs, in which the ray-cells are borne on a stalk (usually rather long), and extend irregularly in all directions; finally, (*c*) candelabra-hairs (Fig. 180, *K*), consisting of a cylindrical, multiseriate main axis, some of the superficial cells of the latter being produced into rays, which are often arranged in tiers. Between these three forms of trichomes transitions are found. Their stalks often possess suberized cell-areas like those

in the stalks of the peltate and stellate hairs. Epidermal secretory cells are frequently[1] present in the pedestals of the tufted, star-shaped and candelabra-hairs (Fig. 180, *D–F*). In many species of the Crotoneae parenchymatous or prosenchymatous sclerenchyma-cells are associated with all the forms of trichomes mentioned above as occurring in this Tribe, with the exception of the candelabra-hairs; these sclerenchymatous cells belong to the mesophyll, but are so intimately connected with the hairs that they may be regarded as an integral part of the latter. In sessile hairs the sclerenchyma-cells immediately adjoin the base of the hair, whilst in the stalked hairs they traverse the stalk. The precise nature of the sclerenchyma-cells varies according to the species. In the simplest case they are slightly sclerosed cells of the palisade-tissue (e.g. in *Croton exuberans*, Müll. Arg. (Fig. 180, *G*), or *C. chamaedryfolius*, Griseb.). In other cases (e.g. *C. cuneatus*, Klotzsch) they are of the same nature, but are more strongly sclerosed. In *C. antisiphyliticus*, Müll. Arg., for example, the sclerenchyma-cells penetrate further into the mesophyll than in the cases mentioned above; at some points they even traverse nearly the entire thickness of the spongy tissue, thus coming into contact with the epidermis on the other side. Not uncommonly the groups of sclerenchymatous fibres, connected with two trichomes, situated opposite one another on the upper and lower side of the leaf respectively, have their ends dovetailed, so that they unite to form a sclerenchymatous column, traversing the entire thickness of the leaf perpendicularly (Fig. 180, *I*). It remains to mention the case, illustrated for example by *C. agoënsis*, Baill. (Fig. 180, *H*), in which the sclerenchymatous fibres, connected with the trichome, terminate in the mesophyll like roots. Regarding the distribution of the sclerenchyma-cells in question, amongst the Crotoneae it may be stated that they have been observed only in *Croton* and *Julocroton*; for further details the reader is referred to the foot-note[2] and to Frömbling's statements. To conclude the subject of the trichomes of complicated type found in the Crotoneae, it remains to mention that they occur in all the genera of this Tribe except *Micrandra*, but that peltate hairs have been met with in *Croton* and *Crotonopsis* only, and candelabra-hairs in *Croton* only.

In the Acalypheae, according to Rittershausen, tufted, stellate and peltate hairs are present, as well as shaggy hairs. The tufted hairs are the most widely distributed (*Acalypha*, *Alchornea*, *Argyrothamnia*, *Bernardia*, *Cephalocroton*, *Coelodiscus*, *Conceveiba*, *Crozophora*, *Mallotus* and *Pera*). They generally consist of a large number of unicellular trichomes, which are sunk side by side in the epidermis. In some cases (*Crozophora*, *Mallotus*) they possess multiseriate stalks of varying

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[1] *Croton agrarius*, Müll. Arg., *C. Cascarilla*, Benn., *C. celtidifolius*, Baill., *C. chrysocladus*, Müll. Arg., *C. ciliato-glandulosus*, Ortega, *C. Cortesianus*, H. B. K., *C. discolor*, Willd., *C. flavens*, Müll. Arg., *C. Frionis*, Müll. Arg., *C. fruticulosus*, Müll. Arg., *C. gracilipes*, Baill., *C. humilis*, L., *C. incertus*, Müll. Arg., *C. lachnocladus*, Mart., *C. linearis*, Jacq., *C. morifolius*, Müll. Arg., *C. origanifolius*, Müll. Arg., *C. pallidus*, Müll. Arg., *C. panamensis*, Müll. Arg., *C. paraënsis*, Müll. Arg., *C. Pohlianus*, Müll. Arg., *C. pulegiodorus*, Baill., *C. pungens*, Müll. Arg., *C. rhamnifolius*, Müll. Arg., *C. Sagraeanus*, Müll. Arg., *C. semivestitus*, Müll. Arg., *C. Soliman*, Cham. et Schlecht., *C. stipulaceus*, H. B. K., *C. subacutus*, Müll. Arg., *C. subvillosus*, Müll. Arg., *C. Urucurana*, Baill., *C. Vauthieranus*, Baill.. *C. vepretorum*, Müll. Arg., *C. xalapensis*, H. B. K. All these species have laticiferous cells also (see p. 746, footnote 2).

[2] In the following enumeration of the species exhibiting a distinct connexion of sclerenchyma with the trichomes, the words 'column,' 'root-like' and 'palisade-cells,' which are added in brackets, indicate a columnar connexion of the sclerenchyma of two opposite trichomes, a root-like branching of the sclerenchyma in the mesophyll, or a palisade-like differentiation of the sclerenchyma as the case may be. It may be added that various modes of differentiation of the sclerenchyma often occur side by side in the same species. The species having sclerenchyma connected with their trichomes are as follows: *Croton agoënsis*, Baill. (root-like), *C. antisiphyliticus*, Müll. Arg., *C. argyranthemus*, Michx., *C. asperrimus*, Benth. (palisade-cells), *C. astroites*, Müll. Arg. (columns), *C. Benthamianus*, Müll. Arg., *C. betulinus*, Vahl (root-like), *C. Billbergianus*, Müll. Arg., *C. capitatus*, Müll. Arg. (columns), *C. caryophyllus*, Benth., *C. Catinganus*, Müll. Arg., *C. caudatus*, Müll. Arg., *C. ceanothifolius*, Baill., *C. chaetocalyx*, Müll. Arg., *C. cneorifolius*, Müll. Arg., *C. compressus*, Lam. (columns), *C. Corchoropsis*, Baill. (root-like), *C. cuneatus*, Klotzsch, *C. floribundus*, Spreng. (columns), *C. glandulosus*, Müll. Arg. (palisade-cells), *C. gratissimus*, Burch. (palisade-cells), *C. longinervius*, Müll. Arg. (root-like), *C. maritimus*, Walt., *C. micans*, Müll. Arg., *C. migrans*, Casar., *C. monanthogynus*, Michx. (columns), *C. Mubango*, Müll. Arg. (palisade-cells), *C. Palanostigma*, Klotzsch, *C. pedicellatus*, H. B. K., *C. tenellus*, Müll. Arg.; *Julocroton argenteus*, Fr. Didrichs., *J. fuscescens*, Baill., *J. stipularis*, Müll. Arg., *J. triqueter*, Müll. Arg. (columns in all four species).

length. In some species of *Alchornea* the tufted hairs graduate into stellate hairs by the spreading out of the ray-cells in a plane parallel to the epidermis. In the stellate hairs of *Aleurites* the ray-cells have thin walls and wide lumina, and are concrescent for half their length. Peltate hairs are described by Baillon as occurring in *Crozophora* (on the ovary only), and by O. Bachmann in species of *Homonoya* and *Pera*. The peltate hairs of *Homonoya* have a four-celled basal plate, and a shield of narrow thin-walled ray-cells, which are united so as to form a cup; the peltate hairs of *Pera* are characterized by the presence of a small lower scale. Shaggy hairs graduating into spines have been met with in *Caperonia*. The following types of hairs require further investigation: the stellate hairy covering found in the genera *Adriana*, *Epiprinus*, *Manniophyton*, *Neoboutonia*, *Symphyllia* and *Sumbavia*, and the scales of *Crotonogyne*, *Leucocroton* and *Pseudocroton* (see Müller Arg. in DC. Prodr., and Bentham and Hooker, Gen. plant.).

In the Hippomaneae, as in the Phyllantheae, the trichomes of the type with which we are dealing are not common. Herbert records stellate hairs with a multiseriate stalk and many rays in only one species each of *Givotia* and *Trigonostemon*, whilst a stellate hairy covering is mentioned by systematists as occurring in the genera *Endospermum*, *Paracroton* and *Ricinodendron* as well. O. Bachmann's statement that peltate hairs occur in *Pausandra* is incorrect. The trichomes which Herbert met with in *Jatropha urens*, L., must be classed as shaggy hairs. They consist of (*a*) a multiseriate, columnar pedestal, which becomes slightly narrower upwards, and apparently encloses an intercellular canal, and (*b*) a rod-shaped terminal cell with thin walls.—In connexion with the Phyllantheae it may be mentioned that the peltate hairs of the anomalous genus *Aextoxicum* possess a small lower scale.

II. Ordinary **glandular hairs** are not very common amongst the Euphorbiaceae. In the Ricinocarpeae small glandular hairs are found in *Bertya gummifera*, Müll. Arg. and *Beyeria viscosa*, Müll. Arg.; they are composed of a short, unicellular stalk and a spherical unicellular head, and in both cases give rise to a considerable deposit of secretion on the surface of the leaf; besides these, club-shaped glands, consisting of a row of cells, also occur in the furrows on the leaves of *Bertya gummifera*. Amongst the Phyllantheae, only glandular, vesicular scales, sunk in small pits in the epidermis, have been recorded (in *Hymenocardia*). The shield is composed of radially arranged cells, and the secretion collects beneath the cuticle. In the Crotoneae glandular hairs may be said to be present only in so far as one may thus describe the epidermal secretory cells projecting like papillae and mentioned above. Amongst the Acalypheae glandular hairs are represented in somewhat greater abundance. External glands of varying size, and having a uni- or biseriate stalk of varied length, and a spherical or oval head of few or many cells, have been shown to occur in species of *Acalypha*, *Cephalocroton*, *Cnesmone*, *Ricinella* and *Tragia*. In *Caperonia* there are long-stalked glandular shaggy hairs, which are visible to the naked eye; the ellipsoidal head encloses clustered crystals, and is sheathed by a secretory epidermis composed of a few elongated prismatic cells. The genera *Coccoceras*, *Coelodiscus*, *Macaranga* and *Mallotus* have large spherical external glands, which are sunk in the surface of the leaf, and have the structure of the well-known Kamala, derived from *Mallotus philippinensis*, i.e. they exhibit abundant formation of secretion beneath the cuticle. Amongst the Hippomaneae, glandular hairs have only been observed in *Acidocroton adelioides*, Griseb. They are small structures sunk in the surface of the leaf, and consist of a stalk-cell and a head, the latter being divided by vertical walls arranged crosswise; the four cells of the head project slightly as papillae.

Glandular organs of a different type are much commoner among the Euphorbiaceae than the glandular hairs described above, namely rather large **external glands** (nectaries), which are visible to the naked eye, and have already occupied the attention of systematists (Baillon, Müller Arg., Bentham and Hooker[1]). Firstly they occur at the base of the petiole, where two or more of

[1] See also Delpino, Mem. Accad. Bologna, 1888, p. 30 et seq.

them are situated. Not uncommonly, however, they replace the stipules, or in certain species they surmount them, the stipules in this case being laciniate and filamentous (e.g. in *Croton ciliato-glandulosus*, Orteg. or *Jatropha multifida*, L.). In other cases they are found at the base of the lamina, sometimes occurring on a special lobe of the latter. Occasionally they are shifted higher up on the lamina, two or more of them being present on the lower side of the leaf; they are rarely met with on the upper side, but frequently occur on the leaf-teeth. For details of their distribution reference must be made to the monograph of Müller Arg.

The anatomical structure of these large glands has hitherto been little investigated; the chief work is that of Frömbling on the Crotoneae. This author classifies the glands as patelliform and morulose. The shape of the patelliform glands (*Croton*, Fig. 180, *M*) recalls that of the perithecium of the Discomycetes; the glands may be either stalked or sessile. The epidermis of the lower arched portion has sclerenchymatous walls, and the superficial cells of the somewhat raised margin of the upper disc-shaped portion have a similar structure. The discoid, depressed surface of the gland is formed by an epidermis, differentiated like a palisade, and having a subcuticular deposit of secretion; beneath this is a second layer of palisade-cells with thicker walls, followed by spongy tissue with cells containing clustered crystals, and surrounding the termination of a vein. The patelliform glands on the upper side of the leaf of *Micrandra bracteosa*, Benth. have an analogous structure, but do not project as hairs. The glandular margin of the leaf in *Croton refractus*, Müll. Arg. (Fig. 180, *N*) may be regarded as a transition to the morulose glands; in *C. refractus* the margin of the leaf is composed solely of a prominent arched group of epidermal cells, elongated like a palisade. In other cases, where the curvature of the surface of the gland is greater, spongy tissue, or even the termination of a vascular bundle, enters into the composition of the glandular body, which thus becomes club-shaped; in this way we obtain morulose glands (Fig. 180, *O*), which are either sessile or possess a multiseriate stalk traversed by a vascular bundle. The secretion of these glands is often considerable and lasting; in some cases however the glands are only functional during the early stages of the organs on which they occur.

Morini examined the nectaries of *Ricinus communis*, L., *Crozophora tinctoria*, L. and *Homalanthus populifolia*, Reinw.; a secretory palisade-like epidermis is found in these species also.

III. **Stinging hairs** have been observed in the genera *Cnesmone*, *Leptorhachis* and *Tragia* (Acalypheae), in *Dalechampia* and in *Jatropha*. According to Rittershausen the stinging hairs in these three genera of the Acalypheae and in *Dalechampia* have a very characteristic type of structure, first noticed by Crüger in *Tragia*, and subsequently by Kohl and Stahl. In their simplest form (Fig. 180, *P*) they consist of a simple unicellular hair, which frequently exhibits a ventricose basal enlargement, whilst the upper pointed portion contains a subulate crystal of oxalate of lime attached to the wall of the hair by strands of cellulose; the upper end of the crystal is sharply pointed, and the lower end is somewhat enlarged, while the very base is provided with two or three small rounded teeth. These simple stinging hairs are accompanied by others of more complicated structure (Fig. 180, *Q*) and consisting of two parts, viz. (*a*) a fairly long pedestal, composed of five contiguous cells, of which one lies in the middle, and differs from the four peripheral cells in having thin walls and possibly containing a secretion; and (*b*) a terminal cell, having its basal wall pitted, and its entire length occupied by a crystal showing the same structure and the same mode of attachment as in the simple stinging hairs. The stinging hairs of *Jatropha urens*, Müll. Arg., &c., agree in structure with the well-known hairs in the nettle. They are unicellular, conical trichomes, about 4 mm. in length, and are surrounded basally by a multicellular pedestal, the upper part of which is differentiated like a cupule. At the apex of the hair there is a head, which is seated obliquely on the end of the trichome;

the head drops off readily owing to the presence of a thin area on the concave side, and a thickened area on the convex side of the wall just below the head.

As structures allied to the stinging hairs we may now describe the hairs containing clustered crystals (which were observed by Rittershausen in *Plukenetia* and *Fragariopsis*) and similar trichomes, which no doubt constitute a protection against herbivorous animals. The hairs containing clustered crystals (Fig. 180, *R–S*) are epidermal cells, which are differentiated as papillae or short hairs, and contain a clustered crystal of oxalate of lime; the latter fills the lumen of the hair, its few (3–6) pointed spines being all directed outwards, and enclosed by the extremely thin outer wall in such a way that the entire structure assumes the appearance of a stellate hair; beneath the cell containing the clustered crystal there is usually a narrow cell, which penetrates to a considerable depth in the mesophyll; this cell possibly contains an irritant substance. Transitions to such hairs, containing clustered crystals, occur in other Acalypheae. *Caperonia* and *Argyrothamnia* possess epidermal cells containing clustered crystals, and having thin outer walls, which project somewhat externally; in *Acalypha* and *Claoxylon* epidermal cells, which project as hemispherical structures, and are filled with a sphaerite of oxalate of lime, have been observed in the leaf and axis.

3. Structure of the Axis. The structural features of the axis are not very uniform, as is to be expected in so large an Order.

The vascular bundles generally have a simple, collateral structure. The following genera possess **intraxylary phloem**: amongst the Eucrotoneae, the genera *Croton, Crotonopsis, Eremocarpus* and *Julocroton*, with the exception of a few species of *Croton*, which belong to the section *Astraea*, and are peculiar in other respects also (*C. comosus*, Müll. Arg., *C. Klotzschii*, Müll. Arg., *C. lobatus*, Müll. Arg. and *C. Paulinus*, Müll. Arg.); amongst the Acalypheae, the genera [1] *Alchornea, Conceveiba, Pera* and *Mallotus integrifolius*, Müll. Arg. (but not other species of *Mallotus*); and amongst the Hippomaneae, the genera *Dactylostemon, Mabea, Senefeldera*, as well as some of the species of *Sebastiania* [2].

Some of the Euphorbiaceous lianes exhibit normal structure even in thick stems (species of *Bridelia, Croton, Dalechampia, Omphalea, Phyllanthus* and *Tragia*, according to Crüger and H. Schenck). Anomalous structure is only known in *Dalechampia* and *Fragariopsis*, where it was discovered by H. Schenck. In both genera (*Dalechampia ficifolia*, Lam. in branches 1·5 cm. thick, *Fragariopsis montana*, Taub. and *F. scandens*, St. Hil.) the anomaly consists in the appearance of secondary strands of wood and bast in the pericycle, whilst in *Dalechampia* there is the additional anomaly of the development of interxylary phloem. The latter has been demonstrated not only in *D. ficifolia*, but also in *D. Leandri*, Baill., *D. pentaphylla*, Lam. and *D. triphylla*, Lam. It is enclosed in bands of thin-walled parenchyma, which are concentrically arranged, and is given off by the cambium internally. It may be added that medullary vascular bundles have been met with in *Ricinus* (Sachs, Dutailly).

The following points may be mentioned regarding the structure of the **wood**. The medullary rays are in most cases narrow; broader rays are found in species of *Aporosa, Dalechampia* and *Phyllanthus*. The mode of arrangement of the vessels and the size of their lumina vary (maximum diameter in *Phyllanthus reticulatus*, Müll. Arg. = ·2 mm., in *Hemicyclia sepiaria*, Wight et Arn. = ·014 mm.). The perforations of the vessels may be either exclusively simple, or both simple and scalariform, or scalariform only, in one and the same species. The bordered pits on the walls of the vessels are sometimes

[1] Pax's statement regarding the occurrence of internal soft bast in all the species of *Mallotus* and in *Aleurites* is incorrect.

[2] See Herbert, loc. cit. p. 49.

of considerable size (diameter of border = ·004 mm. in *Croton pedicellatus*, H. B. K., and ·007 mm. in *Jatropha divaricata*, Sw.). Scalariform bordered pits are occasionally (*Phyllanthus*) present on the common wall of two contiguous vessels. In contact with parenchyma of the medullary rays the walls of the vessels either bear bordered pits only, or bordered accompanied by simple pits, the latter being sometimes of large size. The following paragraphs give a synopsis of the distribution of the perforations, and of the structure of the vessel-wall in contact with parenchyma in the individual genera.

Perforations: I. Simple perforations only are present in: Caletieae: *Caletia*.—Ricinocarpeae: *Beyeria*, *Ricinocarpus*.—Ampereae: *Amperea*.—Phyllantheae: *Actephila* pro parte, *Amanoa*, *Andrachne*, *Antidesma* pro parte, *Breynia*, *Discocarpus*, *Hymenocardia* pro parte, *Lachnostylis*, *Melanthesopsis*, *Petalostigma*, *Phyllanthus*, *Sauropus* pro parte, *Savia*, *Securinega* pro parte.—Crotoneae.—Acalypheae: *Acalypha*, *Adriana*, *Aleurites*, *Argyrothamnia*, *Bernardia*, *Caperonia*, *Cephalocroton*, *Claoxylon*, *Cleidion*, *Coccoceras*, *Coelodiscus*, *Conceveiba*, *Crozophora*, *Homonoya*, *Johannesia*, *Macaranga*, *Pera*, *Plukenetia*, *Ricinella*, *Ricinus*, *Symphyllia*, *Tragia*, *Trewia*.—Hippomaneae: almost all genera, except those given in II and III.—Dalechampieae: *Dalechampia*.—Euphorbieae: *Euphorbia*, *Pedilanthus*.—Gen. anomal.: *Lophopyxis*.—II. Scalariform perforations only in: Phyllantheae: *Actephila* pro parte, *Aporosa* pro parte, *Baccaurea*, *Cyclostemon* pro parte, *Hemicyclia*, *Putranjiva*.—Hippomaneae: *Microdesmis*; *Aextoxicum*.—III. Both scalariform and simple perforations have been observed in: Phyllantheae: *Actephila* pro parte, *Antidesma* pro parte, *Aporosa* pro parte, *Bischoffia*, *Cyclostemon* pro parte, *Drypetes*, *Hieronyma*, *Hymenocardia* pro parte, *Richeria*, *Sauropus* pro parte, *Savia* pro parte.—Acalypheae: *Agrostistachys*, *Alchornea*, *Cnesmone*, *Hevea*, *Leptorhachis*, *Mallotus*, *Mercurialis*, *Pachystroma*, *Sarcoclinium*.—Hippomaneae: *Adenocline*, *Bennetia*, *Hura*, *Manihot*, *Ostodes*, *Paradenocline*, *Pausandra*, *Pogonophora*.

Pitting of the vessel-wall in contact with parenchyma: I. Bordered pits only: Caletieae: *Caletia*.—Ampereae: *Amperea*.—Phyllantheae: in most cases, excepting those genera quoted under II.—Crotoneae (see II).—Acalypheae: *Agrostistachys*, *Argyrothamnia*, *Caperonia*, *Crozophora*, *Mercurialis* (according to Rittershausen, p. 102), *Sarcoclinium*.—Hippomaneae: *Acidocroton*, *Actinostemon*, *Adenopeltis*, *Bennetia*, *Colliguaya*, *Excoecaria*, *Gelonium*, *Givotia*, *Hippomane*, *Mabea* pro parte, *Microdesmis*, *Pausandra*, *Sebastiania*, *Senefeldera*, *Stillingia*, *Trigonostemon*.—II. Simple pits often of large size, sometimes accompanied by bordered pits and by transitional forms between both kinds of pits: Ricinocarpeae: *Ricinocarpus*.—Phyllantheae: *Antidesma*, *Aporosa*, *Baccaurea*, *Bischoffia*, *Hieronyma*, *Hymenocardia*, *Richeria*, *Securinega*.—Bridelieae: *Bridelia*.—Crotoneae: sometimes small (never large) simple pits.—Acalypheae: *Acalypha*, *Adriana*, *Alchornea*, *Aleurites* (according to Rittershausen, p. 46), *Bernardia*, *Cephalocroton*, *Claoxylon*, *Cleidion*, *Cnesmone*, *Coccoceras*, *Coelodiscus*, *Conceveiba*, *Hevea*, *Homonoya*, *Johannesia*, *Leptorhachis*, *Macaranga*, *Mallotus*, *Pachystroma*, *Pera*, *Plukenetia*, *Ricinella*, *Ricinus*, *Symphyllia*, *Tragia*, *Trewia*.—Hippomaneae: *Carumbium*, *Chaetocarpus*, *Cluytia*, *Codiaeum*, *Dactylostemon*, *Erismanthus*, *Hura*, *Jatropha*, *Mabea* pro parte, *Manihot*, *Maprounea*, *Ostodes*, *Pogonophora*.—Dalechampieae: *Dalechampia*.

The wood-parenchyma is generally scantily developed. It is found in greater quantity amongst the Phyllantheae in species of *Amanoa*, *Aporosa*, *Baccaurea*, *Cyclostemon*, *Drypetes*, *Hemicyclia*, *Lachnostylis*, *Richeria*, *Sauropus* and *Savia*; also in *Ricinus* (Acalypheae); and in *Adenocline*, *Givotia*, *Hippomane*, *Paradenocline* and *Pogonophora* (Hippomaneae). The wood-prosenchyma may have either thick or thin walls; in the former case it is sometimes provided with a gelatinous layer, while in the latter case it is occasionally septate. The pits of the prosenchyma are generally simple. Wood-prosenchyma with bordered pits has only been demonstrated in certain genera of the Tribes Caletieae, Phyllantheae and Hippomaneae.

Septation of the wood-prosenchyma has been observed in: Phyllantheae: *Actephila*, *Andrachne*, *Antidesma*, *Bischoffia*, *Discocarpus*, *Hieronyma*, *Hymenocardia*, *Sauropus*.—Bridelieae: *Bridelia*.—Acalypheae: *Acalypha*.

The following genera have wood-prosenchyma with simple pits: Ricinocarpeae: *Beyeria, Ricinocarpus* (very small bordered pits as well).—Phyllantheae: *Actephila, Amanoa, Andrachne* pro parte, *Antidesma, Baccaurea, Bischoffia, Breynia, Discocarpus, Drypetes, Hemicyclia, Hymenocardia, Lachnostylis, Melanthesopsis, Petalostigma, Phyllanthus, Richeria, Sauropus, Savia, Securinega.*—Bridelieae: *Bridelia.*—Crotoneae.—Acalypheae: *Acalypha, Adriana, Agrostistachys, Alchornea, Aleurites, Argyrothamnia, Bernardia, Caperonia, Cephalocroton, Claoxylon, Coccoceras, Coelodiscus, Crozophora, Hevea, Homonoya, Johannesia, Leptorhachis, Macaranga, Mallotus, Pachystroma, Pera, Plukenetia, Ricinella, Ricinus, Sarcoclinium, Symphyllia, Tragia.*—Hippomaneae: *Acidocroton, Actinostemon, Carumbium, Chaetocarpus* pro parte, *Erismanthus, Excoecaria, Givotia, Hippomane, Hura, Mabea, Paradenocline, Pogonophora, Sebastiania, Senefeldera, Trigonostemon.*—Dalechampieae: *Dalechampia.*—Euphorbieae: *Euphorbia, Pedilanthus.*—Gen. anomal.: *Lophopyxis.*

Wood-prosenchyma with bordered pits is present in the following genera: Caletieae: *Caletia.*—Phyllantheae: *Hieronyma,* most species of *Andrachne, Aporosa sphaerocarpa,* Müll. Arg.—Hippomaneae: *Adenocline, Adenopeltis, Bennetia, Chaetocarpus* pro parte, *Codiaeum, Colliguaya, Cluytia* (indistinct), *Dactylostemon, Gelonium, Jatropha, Manihot* (narrow borders), *Maprounea, Microdesmis, Ostodes, Pausandra, Stillingia.*—Acalypheae: *Conceveiba* (according to Rittershausen, p. 67).

The following genera have wood-prosenchyma with both simple and bordered pits: Ampereae: *Amperea.*—Phyllantheae: *Cyclostemon.*—Acalypheae: *Cleidion, Cnesmone, Mercurialis, Trewia.*

Those structural features in the cortex which are common to the Order were mentioned in the general diagnosis. The development of **cork** takes place in the outermost cell-layer of the primary cortex in a large number of genera belonging to the Tribes Ricinocarpeae, Phyllantheae, Bridelieae, Crotoneae, Acalypheae, Hippomaneae and Dalechampieae (see the special papers). In *Actephila* the cork develops in the epidermis; while in *Baccaurea, Andrachne Roemeriana,* Müll. Arg. (but not the other species of *Andrachne*) and *Amperea spartioides,* Brongn. the cork is produced at a considerable depth in the primary cortex. The varied structure of the cork-cells can only be referred to; the cells may be flat or provided with wide lumina, they may have thick or thin walls, and may be sclerosed on one side or on all sides. The outer portion of the **primary cortex** is frequently collenchymatous, and often contains stone-cells (e.g. in special abundance in *Aporosa* and *Hemicyclia*); according to Pax the stone-cells in *Hyaenanche* and *Richeria* are distinguished by being strongly elongated in the vertical direction. Other points requiring special mention are: (*a*) the occurrence of an apparently phellodermal ring of stone-cells in *Johannesia*; (*b*) the presence of a ring of stone-cells in the innermost part of the primary cortex and in contact with the primary hard bast in *Pogonophora*; and (*c*) the peculiar cortical collenchyma found in species of *Pera* having its small intercellular spaces filled with a peculiar, doubly refractive substance (Rittershausen). In most cases the pericycle is formed by isolated groups of bast-fibres, which in young branches frequently unite to form a ring, or by a continuous and composite sclerenchymatous ring. In *Hura* there is a broad parenchymatous pericycle with abundant tannin, situated on the inner side of the sclerenchyma-ring. The bast-fibres of the pericycle are in many cases distinguished by an exceptionally well-marked stratification of their walls, which are either white or yellow. In some cases (in *Amperea spartioides,* Brongn. and probably also in a number of the herbaceous Euphorbiaceae) the sclerenchymatous pericycle is entirely wanting.

A composite and completely or nearly completely continuous ring of sclerenchyma is stated to occur in: Phyllantheae: *Amanoa, Aporosa* pro parte, *Cyclostemon, Drypetes, Hemicyclia, Hieronyma* pro parte.—Acalypheae: *Alchornea* pro parte, *Cleidion, Conceveiba, Hevea, Homonoya, Macaranga* pro parte, *Pera, Symphyllia.*—Hippomaneae: *Actinostemon* pro parte, *Chaetocarpus* pro parte, *Cluytia*

(slightly interrupted), *Dactylostemon*, *Gelonium*, *Maprounea*, *Microdesmis*, *Sebastiania* pro parte and *Senefeldera* (in *Gelonium* and *Senefeldera* the ring of sclerenchyma is composed of stone-cells, and at its outer margin the groups of primary bast-fibres are situated).—An interrupted and composite ring of sclerenchyma occurs in: Phyllantheae: *Actephila*, *Aporosa* pro parte, *Discocarpus*, *Hymenocardia*, *Hieronyma* pro parte, *Lachnostylis*.

It has already been pointed out on p. 739 that typical stratification of the **bast** into hard and soft bast appears to be of rare occurrence (*Bridelia stipularis*, Bl.). In many members of the Order, belonging to the various Tribes one finds small groups of bast-fibres or isolated bast-fibres, the latter sometimes exhibiting a reticulate arrangement in transverse section. The bast-fibres found in the secondary bast resemble those of the pericycle in frequently possessing well-marked stratification of their walls. Two specially noteworthy features may be mentioned: the bast in *Securinega Acidothamnus*, Müll. Arg. shows sclerosis of the parenchyma lying between the groups of secondary bast-fibres, so that a composite and continuous sclerenchymatous ring is formed; and the bast in the species of *Ricinella* (according to Radlkofer's verbal statements) is distinguished by the fact that the innermost, annular portion has a characteristic reddish-brown or brown colour owing to the presence of a secretion. The crystals found in the bast (mostly solitary or clustered crystals) are contained in chambered fibres.

The cells of the **pith** may or may not be lignified. Stone-cells are not uncommonly present in the pith. In *Cluytia alaternoides*, Müll. Arg., the cells of the pith are specially characterized by the curious fact that their transverse walls are provided with large, circular or elliptical perforations at the points of junction with the vertical walls.

Regarding the features presented by the crystals and secretory organs in the axis, see above, pp. 744 and 746 et seq.

DAPHNIPHYLLACEAE.

At this point we may briefly deal with the anatomical features of the genus *Daphniphyllum*, which was raised to the rank of a separate Order by Müller Arg. on account of its small embryo, but is included amongst the Phyllantheae by Bentham and Hooker. I have examined the leaf and axis of *D. laurinum*, Baill., and the leaf of *D. glaucescens*, Bl. There are no special anatomical characters separating the genus *Daphniphyllum* from the Euphorbiaceae. The characteristic features in the structure of the axis, viz. the scalariform perforations of the vessels, and the bordered pitting of the wood-prosenchyma, are also found in the Euphorbiaceae; the same applies to the special structural features of the leaf, viz. the presence of subsidiary cells placed parallel to the pore of the guard-cells, and the occurrence of small cells, containing clustered crystals, in both the upper and lower epidermis. Trichomes and secretory elements are not present. The septation of the pith (without sclerosis) in the two species mentioned above is specially noteworthy.

The following statements may be added regarding the structure of the axis and leaf. The wood possesses narrow, uni- to triseriate medullary rays, the cells of which are somewhat elongated in the vertical direction. The vessels of the wood have small lumina (diameter reaching ·036 mm.), perforations with very numerous bars, and bordered pitting (especially scalariform bordered pits) in contact with parenchyma of the medullary rays. The wood-parenchyma is only scantily developed. Isolated groups of sclerenchymatous fibres are present at the outer limit of the bast. Clustered crystals occur in the bast and in the primary cortex. The leaves of the two species mentioned above have bifacial structure. The stomata are found only on the lower side of the leaf. The vascular bundles of the veins are accompanied by sclerenchyma. In *D. glaucescens* the epidermis on the lower side of the leaf shows papillose differentiation.

BUXACEAE.

The following statements are based on my own examination of the axis and leaf in *Simmondsia californica*, Nutt. (described as *Brocchia glauca* in my 'Holzstruktur'), *Sarcococca pruniformis*, Lindl., *Buxus sempervirens*, L. and *Pachysandra procumbens*, Michx.

As characters common to the whole group, we may point out that the wood-prosenchyma invariably bears bordered pits, the vessels always have bordered pits on the walls in contact with parenchyma, the stomata are never provided with parallel subsidiary cells, and external glands are absent. The perforations of the vessels are usually scalariform only, but are simple in *Simmondsia*. The place of origin of the cork varies; in *Buxus* it is subepidermal, whilst in *Simmondsia* the cork arises in the parenchymatous pericycle, immediately internal to the pericyclic groups of sclerenchymatous fibres. Oxalate of lime is excreted in the form of clustered crystals, ordinary or styloid-like solitary crystals, or as crystal-sand. Internal secretory organs are only present in the form of secretory cells (*Pachysandra*, *Simmondsia*), and never show typical differentiation. The following features require special mention: the anomalous structure of the axis in the monotypic genus *Simmondsia* (appearance of successive rings of growth), and the cortical vascular bundles in *Buxus sempervirens*.

Regarding the structure of the **leaf** in the species mentioned above, the following facts may be added. The leaf is bifacial in *Buxus*, *Pachysandra* and *Sarcococca*, whilst in *Simmondsia* the entire mesophyll consists of palisade-tissue. The species exhibiting bifacial structure have stomata only on the lower side of the leaf; in *Simmondsia*, on the other hand, they are equally distributed on both surfaces. The stomata of *Simmondsia* are somewhat depressed, and have no subsidiary cells. In the remaining genera the guard-cells are surrounded by a rosette of more or less distinct subsidiary cells. *Buxus sempervirens* is distinguished by the specially strong development of crests on the guard-cells. The epidermis in the leaf of *Simmondsia* shows some noteworthy characters: its cells have a small polygonal outline in surface-view, whilst in a transverse section of the leaf they have the shape of palisade-cells, but with a conical tapering of the cell-lumen towards the upper side, and a thick outer wall. Sclerenchyma may (*Buxus*, *Simmondsia*) or may not (*Pachysandra*) accompany the vascular bundles of the veins. In the leaves of *Buxus*, *Pachysandra* and *Sarcococca* I found no oxalate of lime, while in *Simmondsia* I observed that it occurred abundantly in the peripheral portions of the leaf in the form of clustered crystals, and in the middle region in the form of solitary crystals, some of which were differentiated like styloids. In the dried leaf of *Simmondsia* the palisade-parenchyma contains relatively large cells, filled with a yellowish secretion, which at once acquires a brown colour with Eau de Javelle, owing to the presence of tannin. Trichomes have been observed on the leaves of *Pachysandra* and *Simmondsia*. The hairs of *Pachysandra* are simple, have pointed ends, and consist of from two to three cells; those of *Simmondsia* are likewise uniseriate, but are composed of a larger number of cells, which have thick walls, and mostly exhibit a certain amount of articulation, whilst the last one or two cells are relatively short and have thin walls (glandular ?).

In the structure of the **axis** the anomaly presented by *Simmondsia californica* first requires a somewhat detailed description. Even branches from herbarium material show successive rings of growth; these are arranged concentrically, and are separated from one another by narrow rings of lignified parenchyma (conjunctive tissue). The soft bast in the individual vascular rings does not form a continuous annular zone, but consists of isolated groups arranged in concentric series, with parenchymatous conjunctive tissue penetrating between the groups. The secondary rings of bundles arise in the parenchymatous portion of the pericycle, internal to the pericyclic groups of sclerenchymatous fibres.

A transverse section of the **wood** in the Buxaceae shows narrow medullary rays, one or two, rarely three cells in breadth. The vessels are generally isolated, and their diameter is not great (·015–·03 mm.). The bordered pits on the vessels are small in *Buxus* and *Simmondsia*, but relatively large in *Pachysandra* and *Sarcococca*. Bordered pits are also found on those walls of the vessels which are in contact with tissue of the medullary rays. The scalariform perforations have rather numerous bars (30 or more) in *Pachysandra*, *Sarcococca*, and in *Buxus subcolumnaris*, Müll. Arg., which belongs to the section *Tricera*; the bars are

less numerous (not exceeding 15) in the investigated species of *Buxus* belonging to the section *Eubuxus* (*B. balearica*, Willd., *B. japonica*, Müll. Arg., *B. sempervirens*, L. and *B. Wallichiana*, Baill.); *Simmondsia* has simple perforations only. The size of the bordered pits on the wood-prosenchyma agrees with that of the pits on the vessels. Spiral thickening is found on the walls of the vessels in *Simmondsia* and on the walls of the wood-prosenchyma in *Pachysandra*. The wood-parenchyma is in most cases scantily developed, being somewhat more abundant in *Buxus* only.—Turning now to the structure of the **cortex**, we must first refer to the cortical vascular bundles of *Buxus sempervirens*, which were mentioned above. Whether they are present in other species of this genus remains to be determined. They are found singly in the four corners of the branches, and according to J. E. Weiss each bundle is a leaf-trace, which ends blindly in the primary cortex. In *Pachysandra procumbens* the primary cortex includes groups of sclerenchymatous cells, which are either sclerosed on all sides or on one side only; the sclerenchyma-cells of the latter type enclose solitary crystals of oxalate of lime. In *Simmondsia*, *Sarcococca* and *Pachysandra* the bast is limited towards the primary cortex by groups of sclerenchymatous fibres, but these are not present in *Buxus sempervirens*. I have also observed isolated sclerenchymatous fibres in the secondary bast in *Sarcococca*. The mode of development of the cork has already been mentioned above. Secretory elements have been met with in the primary cortex of *Pachysandra procumbens* (herbarium-material), where they occur in the form of secretory cells arranged in longitudinal rows. Oxalate of lime is found in the axis of *Simmondsia* in the form of clustered crystals; in *Pachysandra* the pith and primary cortex contain crystal-sand, and the primary cortex has solitary crystals as well; in *Buxus sempervirens* solitary crystals and small crystalline granules are found in the bast, occurring side by side in the same cells; in *Sarcococca pruniformis* oxalate of lime is not present.

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BALANOPSEAE.

There are scarcely any statements[1] in the literature regarding the anatomy of this small Order, which consists of the single genus *Balanops*, and is regarded as a Tribe of the Cupuliferae by Baillon. The following remarks are based on my own examination of fragments of certain of Balansa's type-specimens kindly sent to me by Prof. Urban (axis and leaf of *Balanops Balansae*, Baill. and *B. microstachya*, Baill., and leaf of *B. Pancheri*, Baill. and *B. Vieillardi*, Baill.). The following features are characteristic of the genus: vessels with extremely small lumina, and scalariform perforations having numerous bars; a composite and continuous ring of sclerenchyma at the outer margin of the bast; superficial development of cork; excretion of oxalate of lime in the form of clustered and solitary crystals; and the absence of trichomes.

The smooth leathery **leaves** have bifacial structure. The epidermis of the leaf is distinguished by having a considerably thickened outer wall and by the polygonal outline of its cells in surface-view. In two of the investigated species, viz. *B. Balansae* and *B. microstachya*, a single layer of hypoderm is present beneath the upper epidermis. The stomata occur only on the lower side of the leaf; their guard-cells are provided with strongly developed cuticular ridges, and are surrounded by several epidermal cells. The vascular bundles of the veins are embedded, and are surrounded by a ring of sclerenchyma. Enlarged terminal tracheides are sometimes found at the ends of the vascular bundles. In *B. Pancheri* and *B. Vieillardi* clustered crystals are rather abundant in the mesophyll.

According to Petit, the basal portion of the **petiole** in *B. Vieillardi* contains three arc-shaped vascular bundles; these become closed higher up to form three rings, but finally open out again.

The **wood** in the genus *Balanops* consists of: (*a*) vessels which have very small, rounded lumina (only attaining a diameter of ·021 mm.), and are mostly isolated; (*b*) wood-prosenchyma with thick walls and narrow lumina; and (*c*) very narrow medullary rays. The vessels, as stated above, have scalariform perforations with numerous bars in all cases. In contact with parenchyma of the medullary rays, the walls of the vessels bear rounded or slit-shaped pits, which may be described as unbordered. In *B. microstachya* the wood-prosenchyma has simple pits, but in *B. Balansae* the pits may be recognized as distinctly bordered when seen in section. The cells of the medullary rays are often considerably elongated in the vertical direction; they are sometimes low, but never show considerable radial elongation.

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[1] Petit, Pétiole, Actes Soc. Linn. de Bordeaux, t. xliii, 1889, p. 18 and pl. i.

Regarding the structure of the **cortex**, the following statements may be made. The cork arises subepidermally (*B. microstachya*), and consists of narrow, tabular cells with rather thick walls. In *B. microstachya* a ring of stone-cells is found adjoining the cork-cambium; this ring is perhaps of the nature of a phelloderm. In *B. Balansae* numerous slightly sclerosed cells occur in the primary cortical parenchyma. The outer limit of the bast is formed by a composite and continuous sclerenchymatous ring, which also includes crystal-cells (with solitary crystals). In the bast we occasionally find solitary crystals, or structures resembling clustered crystals. True chambered fibres containing solitary or clustered crystals are not present in the bast; secondary bast-fibres are also absent, at least in such material of the branch as has been investigated.

URTICACEAE.

The most satisfactory method of dealing with the anatomical features of this Order will be to describe them under different groups, viz.: '1. Ulmaceae' (to include the Tribes Ulmeae and Celtideae); '2. Cannabineae' (the Tribe Cannabineae); '3. Moraceae' (the Tribes Moreae, Arctocarpeae and Conocephaleae); and '4. Urticeae' (the Tribe Urticeae). The Tribe Thelygoneae will be considered in an appendix to these groups, since it differs anatomically from the rest of the Urticaceae in possessing bundles of raphides.

At this point we may give a brief review of the most important anatomical features. The occurrence of silicified or calcified cell-walls, and of similarly constituted cystoliths or cystolith-like structures is very general. In some cases the cystoliths occur independently of the trichomes, this type being found chiefly in epidermal cells (independent cystoliths); in other cases they are met with in the hairs (hair-cystoliths). Independent cystoliths have in the first place been found in certain Ulmaceae and Moraceae, but attain their widest distribution in the Urticeae. A second anatomical feature, viz. the occurrence of laticiferous cells, is confined to *Cannabis* and representatives of the Moraceae. The following important anatomical characters are common to all Urticaceae: the superficial development of the cork in most cases; the considerable length of the bast-fibres[1]; the simple perforations of the vessels; the usually simple pits on the wood-prosenchyma; the lack of a uniform type of stoma; the excretion of oxalate of lime in the form of ordinary solitary and clustered crystals (except in *Thelygonum*, see above). The hairy covering consists of simple, mostly unicellular clothing hairs, and glandular hairs of varied structure. Special forms of hairs are: the bracket-hairs, occurring in some genera; the two-armed climbing hairs of *Humulus*; the stinging hairs of certain Urticeae; and the pearl-glands. In addition to laticiferous tubes and external glands, the secretory system consists of resin-cells and mucilage-receptacles (mucilaginous cells and mucilage-canals).

1. ULMACEAE.

The Ulmaceae agree with the rest of the Urticaceae in certain features presented by the structure of the axis (viz. the superficial development of cork, the almost exclusively simple perforations in the vessels, and the nearly universal occurrence of simple pits on the wood-prosenchyma); also in the frequent occurrence of calcification and silicification, and more especially of cystolith-like

[1] These long bast-fibres are multinucleate in *Urtica dioica* and *Cannabis sativa* (Treub and Kallen).

structures. The latter are either independent cystoliths, or hair-cystoliths, or cystotyles. As a point of distinction from the Cannabineae and Moraceae, the absence of laticiferous cells in the Ulmaceae deserves notice. The only internal secretory elements which have been observed are mucilage-cells (in the bast of species of *Ulmus*, and in the mesophyll of species of *Celtis*, *Gironniera* and *Phyllostylon*), if we exclude the gelatinization of the epidermis of the leaf found in many species. The type of stoma is not uniform: similarly the pericycle shows varied differentiation. Oxalate of lime occurs in the form of clustered and solitary crystals, the latter sometimes resembling styloids in shape as in the neighbourhood of the primary hard bast of *Celtis*. The hairy covering consists of clothing and glandular hairs, both of which show little diversity of form, the clothing hairs being mostly unicellular. Other special features in the structure of the leaf are: papillose differentiation of the lower epidermis (species of *Celtis*); and development of hypoderm on the upper side of the leaf (species of *Aphananthe*, *Celtis*, *Gironniera*, *Holoptelea*, *Parasponia*, *Trema*).

The **leaf-structure** of the Ulmaceae has been investigated especially by Priemer [1]. The following statements may be cited regarding the integumentary tissue of the leaf. The lateral margins of the **epidermal cells** are either straight or undulated. Certain species of *Ulmus* and *Celtis* are distinguished by the development of strong cuticular ridges, especially on the lower side of the leaf. Papillae are found on the lower side of the leaf in certain species of *Celtis* [2]. All the investigated species of *Ulmus*, *Phyllostylon*, *Planera*, *Zelkova* incl. *Hemiptelea*, *Ampelocera*, *Celtis*, *Parasponia*, *Gironniera*, *Chaetacme*, and some of the species of *Trema* exhibit gelatinization of the epidermis of the leaf. Another feature is the 'two-layered epidermis' found in species of *Aphananthe*, *Celtis*, *Gironniera*, *Holoptelea*, *Trema* and *Parasponia* [3], the lower layer of cells usually differing from the upper. The **stomata** are generally present only on the lower side of the leaf, but in *Trema aspera*, Bl. and some species of *Celtis* they also occur on the upper side. The guard-cells usually lie on a level with the epidermis, but in the species with a papillose epidermis, and in *Hemiptelea Davidii*, Pl. they are depressed, while in *Trema amboinensis*, Bl. and other species they are elevated. With regard to the subsidiary cells, Priemer makes the following rather vague statement: 'The stomata are invariably enclosed by accessory subsidiary cells'; in *Ulmus campestris*, L. I found the stomata surrounded irregularly by a number of ordinary epidermal cells, while in *Celtis tetrandra*, Roxb. one of the neighbouring cells on either side of the pore is placed parallel to the latter. The **leaf-structure** is mostly bifacial, but is subcentric in some species of *Celtis*. The palisade-tissue consists of one or more layers, the number being sometimes constant for certain species, or even genera. In some species of *Celtis* the lateral walls of the palisade-cells are finely undulated. The spongy tissue either contains large lacunae (*Planera*, *Ulmus*, *Zelkova*) or is dense. In certain species of *Celtis*, *Gironniera* and *Phyllostylon* [4], mucilage-cells occur in the mesophyll [5]. The vascular bundles

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[1] Priemer's work deals with the following genera: (1) Ulmeae: *Ulmus*, *Holoptelea*, *Phyllostylon*, *Planera*; (2) Celtideae: *Zelkova* incl. *Hemiptelea*, *Ampelocera*, *Celtis*, *Trema*, *Parasponia*, *Aphananthe*, *Gironniera*, *Chaetacme* and *Celtidopsis* (*Mertensia pubescens*, Kth., incorrectly named *Mertensia citrifolia* or *Celtidopsis citrifolia* by Priemer). Priemer's nomenclature of the species is on the whole retained here, although in his work the same species sometimes figures under several synonyms; I have only corrected the numerous misprints.

[2] See Priemer, loc. cit., p. 462.

[3] See Priemer, loc. cit., p. 424, foot-note 1.

[4] *Celtis aculeata*, Sw., *C. dichotoma*, Ruiz, *C. jamaicensis*, Pl., *C. latifolia*, Pl., *C. mauritiana*, Pl., *C. paniculata*, Pl., *C. rigescens*, Pl.; *Gironniera celtidifolia*, Gaud.; *Phyllostylon brasiliensis*, Capan., *P. rhamnoides*, Taub.

[5] I do not know what Priemer means by the 'free sclerenchymatous elements' of some species

of the **veins** are either accompanied by sclerenchyma only (*Ulmus, Planera, Zelkova, Celtis* pro parte, *Gironniera, Aphananthe* pro parte) or by a sheath of large parenchymatous cells devoid of chlorophyll (*Hemiptelea, Phyllostylon, Celtis pro parte, Trema, Parasponia, Aphananthe pro parte*); *in other* cases neither sclerenchyma nor a parenchymatous sheath is present (*Celtis cinnamomea*, Lindl., *Ampelocera, Aphananthe philippinensis*, Pl.). Vertically transcurrent veins are found in the genera *Gironniera, Hemiptelea, Parasponia, Planera, Trema, Ulmus, Zelkova, Celtis* pro parte, and *Phyllostylon rhamnoides*, Taub.

Oxalate of lime is present in the form of ordinary solitary and clustered crystals. Both forms of crystals are found in the leaf in the genera *Aphananthe, Celtis, Gironniera, Holoptelea*[1], *Phyllostylon* and *Ulmus*, the clustered crystals occurring in the mesophyll, the solitary crystals accompanying the vascular bundles of the veins. Solitary crystals alone have been observed in the leaf in *Ampelocera* (only in the petiole) and *Zelkova*, clustered crystals alone in *Hemiptelea, Parasponia, Planera* and *Trema*, while in *Ampelocera* neither clustered nor solitary crystals are present.

The **hairy covering** consists of clothing and glandular hairs. The former have pointed apices, and are mostly unicellular, or as an exception (*C. Kraussiana*, Bernh.) bicellular. The walls of the hairs are mostly thick, and are frequently calcified or silicified; the outer surface is sometimes (species of *Aphananthe, Celtis, Gironniera, Trema*) furnished with calcified warts, and not uncommonly a cystolith-like body springs from the lateral wall. Special forms of trichomes are: the long and narrow clothing hairs of *Celtis boliviensis*, Pl., *C. Tala*, Gill. and *Zelkova cretica*, Spach; the trichomes of *Ampelocera Ruizii*, Klotzsch, which have thin walls, and are broadest at the middle, not at the base; and the hairs of certain species of *Trema* (such as *T. amboinensis*, Bl.), which likewise have thin walls, sometimes contain cystoliths, and form a felt-like covering on the lower side of the leaf. Glandular hairs are present in all the genera examined by Priemer. They generally have a unicellular or uniseriate stalk of variable length, and a head composed of one or several cells.

The shape of the glandular hairs varies even within the limits of a genus. In the simplest case (species of *Celtis* and *Trema*) the glandular hairs consist of a row of cells with a more or less distinct demarcation of the terminal cell. In other species of *Trema* the hairs are composed of a double row of cells. *Ulmus, Planera, Phyllostylon, Aphananthe* and *Hemiptelea* have club-shaped glandular hairs consisting of about three cells lying in a row, the terminal cell being occasionally somewhat swollen. In *Ampelocera* there are glandular hairs with a unicellular stalk, and a club-shaped head divided by horizontal and vertical walls; in *Gironniera* there are hammer-shaped external glands with a unicellular stalk, and a head divided by vertical walls only, whilst in certain species of *Celtis* the glandular hairs are derived from uniseriate hairs by enlargement of the distal cells which further undergo vertical divisions.

In some cases the marginal teeth of the young leaves also produce a secretion, e.g. in *Ulmus campestris*, according to Reinke. These teeth include the termination of a vein; mucilage is found in the epidermis and the subjacent tissue, and a few stomata occur above the end of the vein

Silicification and **calcification** are common phenomena, as stated above.

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of *Celtis*, described on p. 438; possibly the enlarged terminal tracheides are referred to. In the two species which I had at my disposal for checking this observation (*C. paniculata*, Pl. and *C. tetrandra*, Roxb.) I found nothing to which such a term would be applicable.

[1] In the general part of Priemer's work *Phyllostylon* is not included amongst the genera enumerated as having both solitary and clustered crystals in the leaf; in place of this genus, however, *Hemiptelea* is quoted, involving a contradiction of the statements in the special portion of the same treatise. In the general part *Holoptelea* is given amongst the genera which have clustered crystals only, while, according to the special part, solitary crystals are present in the petiole of *Holoptelea* Such contradictions are unfortunately not uncommon in Priemer's work.

In some cases the silicification, besides affecting the walls of the hairs, frequently extends to the outer walls of the epidermal cells and the adjacent lateral walls. In other cases the silicified parts are protuberances of the cell-wall, the shape of which may graduate into that of cystoliths. These protuberances occur not only in the integumental tissue, but also in the mesophyll. The silicification is specially strong in *Celtis, Chaetacme, Hemiptelea, Holoptelea* and *Trema*. In many cases calcification accompanies the silicification. The calcification of the walls of the hairs has already been mentioned above. We may follow Priemer in dividing the calcified cystolith-like structures into cystotyles and cystoliths. According to Priemer the cystotyles comprise all encrusted structures which have no stalk and no stratification, while the cystoliths are those which are provided with a stalk, or are stratified, or exhibit both these features. The cystolith-like structures are almost always confined to the integumentary tissue; they are restricted to the mesophyll in *Celtidopsis* only. Cystoliths have been observed in the genera *Ampelocera, Celtis, Chaetacme, Hemiptelea, Holoptelea, Parasponia, Phyllostylon* and *Trema*, and cystotyles in all the investigated genera. The cystoliths are either independent, or occur in the hairs. The independent cystoliths are found in epidermal cells, which are enlarged towards the mesophyll, only a small portion of the wall of the cell in most cases reaching the surface of the leaf; it is to this portion of the wall that the stalk of the cystolith is attached. Cystoliths of the second type, viz. hair-cystoliths, occur in the trichomes. The lithocysts containing the independent cystoliths usually lie with their outer wall on a level with the epidermis, and rarely (*Celtis brasiliensis*, Pl.) occur in a superficial depression. The independent cystoliths are as a rule botryoidal, cylindrical, or spherical in shape, all these different forms being found in the genus *Celtis*. Among rarer forms are reniform or arc-shaped cystoliths (*Celtis pubescens*, H.B.K., &c.), or mushroom-like cystoliths (*Chaetacme aristata*, Pl.). The cystoliths in the hairs are pear-shaped, and are seated on the lateral wall, near the base of the hair. The occurrence of cystoliths in mucilaginous epidermal cells is specially noteworthy (species of *Chaetacme* and *Trema*).

In dealing with the systematic value of these structures Priemer distinguishes the following types of cystoliths, employing the terms introduced by Mez in his study of the cystoliths of the Cordiaceae: I. Independent cystoliths, i.e. such as occur independently of the hairs; at the most the outer wall of the lithocyst terminates in a small point. *Ampelocera* (containing very little lime and only occurring in the upper epidermis of the leaf); *Celtis* (except *C. Kraussiana*, Bernh.; some of the species also have types II and III); *Chaetacme* (mushroom-shaped, mostly in mucilaginous epidermal cells, and only on the upper side); *Holoptelea* (only in the lower epidermis); *Phyllostylon* (accompanying type II); *Trema* (in mucilaginous epidermal cells in a few of the species; accompanied by type II, and in some of the species by III also); *Celtidopsis* (only in the mesophyll). II. Hair-cystoliths: *Celtis* pro parte (accompanied by type I); *Phyllostylon* (accompanied by I); *Trema* (accompanied by I, and in some of the species also by III). III. Spherical cystoliths, i.e. hair-cystoliths, surrounded by epidermal cells containing cystotyles, the whole group forming small false scales: *Celtis Kraussiana*, Bernh. and other species of *Celtis* (the latter also having types I and II); *Hemiptelea*; *Parasponia* (accompanied by II); *Trema* (accompanied by I and II). IV. Smaller cystoliths, often poor in carbonate of lime and rich in silica, and seated in groups of 2–5 in the corners of adjacent epidermal cells: in all the genera and of no special systematic value.

According to Priemer the base of the **petiole** contains either an arc-shaped vascular bundle (*Celtis, Trema, Zelkova, Holoptelea, Aphananthe*), or a ring of wood and bast (*Ulmus, Planera, Phyllostylon, Hemiptelea, Chaetacme*), or three vascular bundles (*Gironniera*). According to Petit, three vascular bundles enter the petiole in species of *Celtis, Ulmus* and *Planera*.

The structure of the **axis** has been specially examined by me with reference

to the nature of the wood in *Ulmus campestris*, L., *Holoptelea integrifolia*, Pl., *Planera aquatica*, Gmel., *Celtis occidentalis*, L. and *Aphananthe aspera*, Pl., and by Möller with reference to the cortex in species of *Ulmus* and *Celtis*. In *Ulmus* the medullary rays of the **wood** reach a breadth of seven cells even in material from branches, the cells being much elongated radially, and exclusively in that direction ; in the remaining genera the medullary rays are narrower, reaching a breadth of three cells, and some of the cells are elongated in the vertical, some in the radial direction. The vessels vary as to the size of their lumina and the mode of their arrangement. In *Holoptelea*, the vessels, which are mostly isolated, more rarely arranged in radial series of 2–3, attain a diameter of ·09 mm. ; in *Planera* the majority of the vessels form radial rows, and their diameter only reaches ·04 mm. ; in *Ulmus* the diameter of the vessels in the spring-wood reaches ·15 mm., and they are isolated, while the vessels of the autumn-wood have smaller lumina and form tangential groups. On the common walls between contiguous vessels rather large bordered pits occur (diameter of border in *Ulmus* as much as ·009 mm., in other cases ·004 mm.). In contact with parenchyma of the medullary rays, the walls of the vessels are also mostly provided with distinct bordered pits. Spiral thickening of the vessel-wall has been observed in *Ulmus campestris* (according to Hesselbarth in *U. pedunculata* also), and in *Aphananthe aspera*. The perforations of the vessels are simple, and round or elliptical. Scalariform perforations with 1–6 bars have only been met with in *Planera aquatica*, where they occur in the neighbourhood of the primary wood, elongated elliptical perforations being also present. The wood-parenchyma is sometimes (*Celtis*, *Holoptelea*) developed in considerable quantity. In *Planera* the wood-prosenchyma is provided with pits having a small border (similar to those of *Betula*), but in other cases it bears simple pits. The wood-fibres frequently have relatively wide lumina and rather thick walls. In some cases (species of *Celtis*, *Holoptelea* and *Ulmus*) the size of the lumen is diminished by the presence of a gelatinous layer. It remains to mention that in the heart-wood and pith of certain species of *Ulmus* and *Celtis* it has been demonstrated that carbonate of lime forms a component part of the cell-contents (Molisch and Priemer).

The outermost cell-layer of the **cortex** is sometimes (*Celtis*, *Ulmus*) silicified. According to Möller, the development of cork takes place subepidermally. The cork consists of cells with wide lumina, and in *Celtis* contains stone-cells. As is well known, *Ulmus suberosa*, Mch. is characterized by a massive development of the superficial periderm. The pericycle contains isolated bundles of bast-fibres in *Ulmus*, and a composite and continuous ring of sclerenchyma in *Celtis*. In both genera the secondary bast includes groups of long, smooth bast-fibres, which occasionally give rise to a stratification of the bast. In the older cortex of *Celtis* the bast-parenchyma becomes sclerosed. The sieve-tubes have simple sieve-plates with coarse meshes. The medullary rays of the bast contain no crystals, but solitary and clustered crystals are fairly common in other parts of the cortex ; in *Ulmus* the solitary crystals in the neighbourhood of the primary bast are rod-shaped (resembling styloids). Of secretory elements, mucilage-cells are found in the bast of *Ulmus* : they have large rounded lumina, and are somewhat elongated in the vertical direction ; according to Möller they vary in abundance, and are quite absent in some specimens.

According to Gris, the **pith** in *Planera* is entirely composed of active cells with thick walls, whilst in *Ulmus* and *Celtis* the central portion consists of rather large, empty cells with thin walls, and the peripheral portion is formed by relatively small active cells with thick walls [1].

[1] It is not easy to understand how Gris comes to the conclusion, from these data, that *Celtis* should be separated from *Ulmus* and *Planera* as an independent group.

2. CANNABINEAE.

Cannabis and *Humulus*, like the other Urticaceae, exhibit the following features: simple perforations in the vessels; wood-prosenchyma with simple pits; secondary hard bast; long bast-fibres (as much as 22 mm. in length in *Cannabis*); cystolith-like structures; unicellular clothing hairs often containing cystoliths; and glandular hairs, the heads of which are mostly divided by vertical walls only. Laticiferous cells have only been observed in *Humulus*. The stomata have no special neighbouring cells. Oxalate of lime takes the form of clustered crystals.

To this brief diagnosis we may add some information regarding the laticiferous tubes, the hairy covering, the cystoliths, &c., and the structure of the petiole. The **laticiferous tubes** of *Humulus* are found in the parenchymatous pericycle, on the inner side of the primary groups of hard bast. According to Holzner the laticiferous tubes do not appear to be present in the embryo. Further investigation is required to determine whether these elements occur

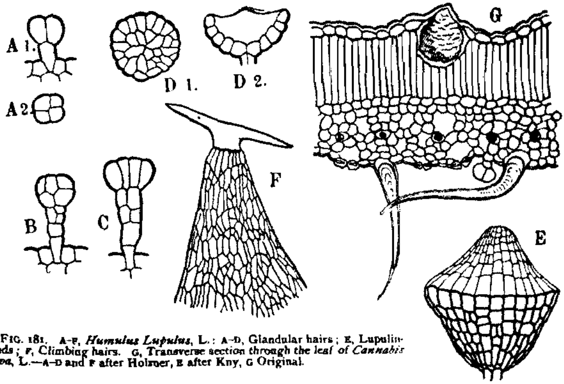

FIG. 181. A–F, *Humulus Lupulus*, L.: A–D, Glandular hairs; E, Lupulin-glands; F, Climbing hairs. G, Transverse section through the leaf of *Cannabis sativa*, L.—A–D and F after Holzner, E after Kny, G Original.

in *Cannabis*, or are really absent, as is apparently the case [1]. The clothing **hairs** are mostly unicellular, more rarely (*Humulus*) uniseriate; they vary in length. As in other Orders possessing cystoliths, we find an antagonistic relation between the development of hairs on the one hand, and of cystoliths on the other (Fig. 181, *G*). The large cystoliths on the upper side of the leaf of *Cannabis sativa*, L. are contained in trichomes, the basal portion of which is strongly swollen, and penetrates into the mesophyll, while the actual body of the hair is often considerably reduced; on the other hand the longer hairs on the lower side of the leaf only include small cystoliths, and in these the stalk of the cystolith may be said to be formed by the body of the hair, which has become solid owing to calcification and silicification; in other cases these

[1] Chauveaud's statement (loc. cit., p. 119) that laticiferous tubes occur in *Cannabis* is based on the fact that Engler ascribes them quite generally to the members of his Order Moraceae (including the Cannabineae). According to Chauveaud laticiferous tubes are not present in the embryo of *Cannabis*.

long hairs only possess a calcified apex. In the cells adjoining the large hair-cystoliths, cystotyles sometimes occur. The climbing-hairs found in the hop (Fig. 181, *F*) are a special form of clothing hair. They are unicellular malpighian hairs with equal or unequal arms, and a strongly silicified wall, and are either directly inserted in the epidermis or seated at the apex of a multicellular pedestal. These hairs are connected with the ordinary clothing hairs by transitional forms. The glandular hairs of *Humulus* exhibit a series of forms, which have been described in detail by Holzner (Fig. 181, *A–E*); the following types are found: (*a*) stalked capitate external glands, with a unicellular, or uniseriate and then locally (i.e. in the upper part) biseriate stalk, and a spherical head, which is composed of four or more cells separated by vertical walls, or is divided into a still larger number of cells by both horizontal and vertical walls; (*b*) discoid glands with a unicellular stalk and a disc-shaped head consisting of a single layer of cells; (*c*) finally glands with a crateriform head, composed of a single layer of cells, and exhibiting an abundant accumulation of secretion beneath the cuticle. *Cannabis* has discoid glands similar to those of *Humulus*, and also small external glands with a unicellular stalk, and a head which is either unicellular or bicellular, owing to the presence of a vertical wall. The teeth on the young leaf of *Humulus* are also glandular, being provided with a secretory palisade-like epidermis. The characteristic region of the **petiole** contains an arc-shaped fibrovascular system in *Cannabis* and *Humulus*; in the latter genus the seven component vascular bundles which enter the petiole, can be distinctly recognized in the arc of vascular tissue.

3. Moraceae.

The Moraceae are specially distinguished by the presence of laticiferous cells. Certain other features they have in common with the rest of the Urticaceae; these are: the simple perforations in the vessels; the simple pitting of the wood-prosenchyma; the superficial development of the cork; the presence of cystolith-like structures; and the frequent occurrence of very long bast-fibres. The stomata usually have no special subsidiary cells. The hairy covering consists of: (*a*) simple unicellular hairs, which are sometimes (*Artocarpus, Dorstenia, Broussonetia, Cecropia*) bent like a hook at the apex; (*b*) uniseriate hairs (*Ficus* pro parte, *Cecropia*); and (*c*) glandular hairs of varied structure (in some cases pearl-glands). Oxalate of lime is excreted in the form of solitary and clustered crystals. The following internal secretory organs are present: resin-cells (*Artocarpus*), tanniniferous idioblasts (*Ficus*), and mucilage-canals (*Cecropia, Conocephalus*). Special features in the leaf are the occurrence of hypoderm (species of *Ficus* and *Conocephalus*), and of clustered crystals in the epidermis (species of *Antiaris, Artocarpus, Ficus, Maclura*).

A detailed investigation of the structure of the **leaf** has not yet been made. In the representatives of the three Tribes examined by me (*Morus alba*, L., *Artocarpus incisa*, L. f. and *Conocephalus suaveolens*, Bl.) the stomata are surrounded in the first two species[1] by a number of epidermal cells irregularly arranged, in *Conocephalus suaveolens*[2] by three subsidiary cells. Gelatinization of the epidermis of the leaf has been observed in *Morus alba*, and by Richter in *Antiaris toxicaria*, Lesch. and species of *Cecropia*. Hypoderm has been found in *Conocephalus suaveolens*, species of *Cecropia* and numerous species of *Ficus* (see De Bary and Möbius); it occurs either on both sides or

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[1] The same is the case in *Antiaris*, according to A. Richter, and in *Ficus*, according to Strasburger. In *Ficus* the cells immediately surrounding the pairs of guard-cells are cut off by secondary divisions from the cells adjoining the mother-cell of the guard-cells (Strasburger, in Pringsheim's Jahrb., Bd. v, 1866–7, p. 332 and Tab. xli).

[2] Also in *Dorstenia*, according to Benecke.

only on the upper side of the leaf. In *Brosimopsis lactescens*, Sp.-Moore and *Ficus Carica* the upper epidermis consists locally of two layers. The genus *Cecropia* has vertically transcurrent veins (Richter). A noteworthy feature is the occurrence of clustered crystals in the integumentary tissue. These crystals occupy small epidermal cells in *Antiaris sacciodora*, Dalz. and *Artocarpus communis*, Forst., according to A. Richter, and in *Maclura tricuspidata* and '*Ficus indica*,' according to Möbius; in the first three species these cells form small groups. In *Ficus elastica* and *F. macrophylla* clustered crystals are found in the hypoderm (Möbius). It remains to mention the peculiar small pits, warts or spots (forming hydathodes), which are found in many species of *Ficus*, in *Conocephalus ovatus* and *Cecropia Schiedeana*; they are situated on the upper side of the leaf, and generally occur above the points of junction of the veins, or more rarely are restricted to the margin of the leaf. They are due to the presence of a group of cells resembling an epithema and containing the termination of a group of tracheae belonging to the vascular system; above the epithema there is a group of water-pores (De Bary, Haberlandt, Möbius).

The distribution of the **laticiferous tubes** has hitherto been insufficiently investigated from an anatomical point of view. By no means all the Moraceae are stated by systematists to have latex, but that does not exclude the possibility of laticiferous tubes occurring throughout the Tribe, though in some cases with contents which are not milky. In Bentham and Hooker's Gen. Plant., and in DC. Prodr. the following genera are described as lactescent: amongst the Moreae—*Bleekrodia, Taxotrophis, Maillardia, Broussonetia, Allaeanthus, Bagassa, Chlorophora, Maclura, Pachytrophe* (succo opalino), *Paratrophis, Pseudomorus, Morus, Ampalis* (succo opalino), *Trophis, Sloetia* and *Dorstenia*; amongst the Artocarpeae—*Ficus, Brosimum, Lanessania, Antiaris, Olmedia, Castilloa, Perebea, Noyera, Artocarpus, Sahagunia, Clarisia, Balanostrebus* and *Sorocea*; and amongst the Conocephaleae—*Cecropia* and *Coussapoa*. According to Pöppig, *Trymatococcus* (*Morea*) has no latex; the genera *Pseudolmedia, Helicostylis* and *Batocarpus* (Artocarpeae) are described as (?) lactescent. According to Trécul, laticiferous tubes are not present in *Conocephalus suaveolens*, but they have been shown to occur in the recently established Artocarpeous genus *Brosimopsis*, Sp.-Moore. According to Schmalhausen and Chauveaud, the initials of the laticiferous system in the Moraceae are found in the nodal plane of the embryo; they form two groups, each composed of 4–5 cells, which are situated peripherally in the central cylinder at points corresponding to the depressions between the two cotyledons. In the mature plant they are present both in the axis and leaf; those in the axis occur in the pith, primary cortex, pericycle and bast. The medullary laticiferous tubes are often connected with those in the cortex through the medullary rays. Those occurring in the secondary bast are not of secondary origin, but are merely branches of the cortical laticiferous system. The course of the laticiferous tubes in the leaf has only been examined in detail in *Ficus*; we may follow Pirotta and Marcatili, as well as Groom and Scott, in distinguishing two cases. In some of the species of *Ficus* (e.g. *F. laurifolia*) the laticiferous tubes are only found accompanying the vascular bundles of the veins; in other species (e.g. *F. elastica, F. religiosa*, &c.) the main branches of the laticiferous tubes do not leave the vascular bundles of the veins, but they send out branches into the mesophyll, and these sometimes traverse the hypodermal aqueous tissue as far as the epidermis, or even (*F. retusa*) reach the cuticle. In *Ficus Carica, F. elastica, Broussonetia papyrifera, Maclura aurantiaca* and *Morus nigra* the contents of the laticiferous tubes include large grains, the nature of which has not been determined; these grains frequently show stratification, which was first observed by Caruel. The laticiferous tubes also contain nuclei, according to Treub.

The spherical **secretory** cells with resinous contents mentioned above have been observed by A. Richter in the spongy tissue of the leaf in *Artocarpus communis*, Forst. and *A. echinata*, Roxb. (but not in *A. integrifolia*, L.). The mucilage-canals are probably of lysigenous origin, and are found in the pith in species of *Cecropia* and in *Conocephalus suaveolens* (see also Trécul). The tanniniferous idioblasts, which were described by Möbius as mucilage-cells, have contents which are strongly refractive in the living, and reddish-brown in the dry plant; these elements are present in the palisade-tissue (as enlarged cells of this tissue), and in the neighbourhood of the vascular system of the veins in *Ficus australis* (= *F. rubiginosa*).

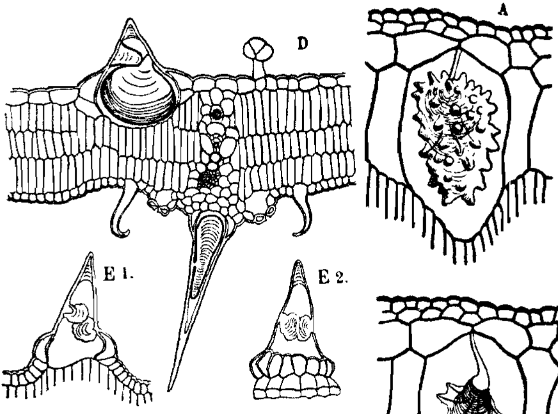
Calcification and **silicification** of the cell-wall are two common phenomena in the Moraceae, and often accompany one another. The silicification affects cells of the different tissues, the hairs and cystoliths. The following cases of silicification may be mentioned as examples: the walls of the epidermal cells in species of *Ficus* and *Morus* are silicified; so also are the walls of the outermost cell-layer of the primary cortex in species of *Artocarpus, Brosimum, Coussapoa, Ficus, Morus, Pourouma, Sorocea, Trophis* and *Trymatococcus*, and the walls of the hairs in *Ficus*; according to Kohl, the walls of the papillose epidermal cells and of the trichomes in *Dorstenia nervosa*, Desv. are silicified to such an extent that the lumina of the cells almost entirely disappear. In the case of the cystoliths, silicification sometimes (*Ficus Sycomorus*, according to Miliarikis) affects the lithocysts, and very frequently the stalk and the adjacent portion of the nucleus of the cystolith. In *F. Sycomorus* moreover, according to Miliarikis, a siliceous shell may be formed round the head of the cystolith, thus enclosing it, or the entire cystolith may be impregnated with silica.

The **cystoliths**, which have been chiefly examined in the leaf, are independent in some cases, whilst in others they are hair-cystoliths. Their exact distribution has not yet been determined. In Kohl's treatise, in which the statements of earlier observers are combined with his own observations, cystoliths are described as occurring in *Ficus, Morus, Broussonetia* and *Chlorophora* (Kohl's *Maclura tinctoria* = *Chlorophora tinctoria*, Gaud., non *Maclura*, Nutt.); to these I am able to add *Conocephalus*. According to Payen, cystoliths are absent in *Dorstenia*. The cystoliths found in the leaf, when not present in the hairs, are generally[1] situated in epidermal cells, which often penetrate deeply into the mesophyll, while the portion of their wall reaching the surface of the leaf varies in area. In most cases the cystoliths occur singly; more rarely several of them are found in the same cell; within the limits of the same genus (*Ficus*) they may predominate sometimes on the upper, sometimes on the lower side of the leaf. Only the independent cystoliths show typical differentiation; they are provided with a distinct stalk attached to the outer wall, exhibit distinct stratification, and sometimes also show radial strands, whilst in the hair-cystoliths these structural features are more or less reduced.

The cystoliths have been most thoroughly investigated in the genus *Ficus* by Kohl and Möbius, and their results, which are based on the examination of a relatively small number of species, are sufficient to show what valuable data will be obtained for specific diagnosis when further investigations are carried out. The cystoliths of *Ficus elastica* (Fig. 182, *A–B*) are those best known; they are ellipsoidal in shape, with a verrucose surface, and occupy large idioblasts, adapted to the shape of the cystoliths and occurring in the integumentary tissue of the leaf, especially on the upper side. They are strongly impregnated with carbonate of lime, and to some extent (chiefly in the stalk) with silica as well; in section (as may be specially clearly seen after decalcification) they exhibit very fine stratification

[1] In no case do they occur in the cells of the assimilatory tissue, but they are sometimes present in the parenchyma of the veins of the leaf.

about the end of the stalk as a centre, and an additional system of delicate, frequently branched strands, radiating from the same point and terminating in the warts.



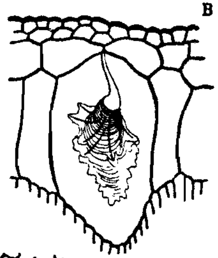
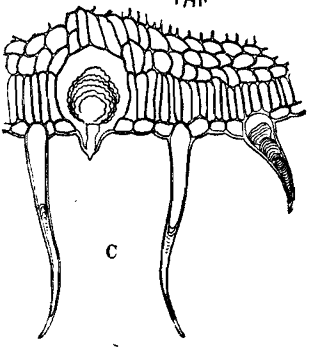


FIG. 182. A–B, Cystoliths of *Ficus elastica*, Roxb. in the hypodermal tissue on the upper side of the leaf: B, after decalcification with hydrochloric acid. C, Cystoliths and cystolith-hairs on the lower side of the leaf of *Ficus Carica*, L. D–E, *Broussonetia papyrifera*, Vent.: D, Transverse section of the leaf with cystolith-hairs, bracket-hairs and glandular hairs; E, Cystolith-hairs on the upper side of the young leaf.—Original.



In *F. Cooperi*, especially in the lower epidermis, there are spherical cystoliths in which the stalk is short and thick, and the surface bears broad flat warts. The cystoliths on the upper side of the leaf in *F. religiosa* are characterized by the fact that their lithocysts do not differ in size from the remaining epidermal cells, and are arranged in groups. In *F. Carica* the cells containing the cystoliths show a tendency to develop into trichomes (Fig. 182, *C*). In the leaf of this species we find the following structures: (*a*) large, distinctly stalked cystoliths occurring on the lower side of the leaf in enlarged papillose epidermal cells provided with a small solid hair-like tip; (*b*) hair-cystoliths; and (*c*) hairs, of which the upper portion is filled with calcified caps of cellulose. In a species which Kohl describes as *F. cerasifera*, he found (besides other types) large cystoliths of an irregular tuberous shape, having neither warts nor strands. For further examples see Kohl and Möbius.

According to Bokorny, the cystoliths of *F. cordata*, Thunb., which give rise to transparent dots in the leaf, are not calcified, but appear to be suberized, to judge by the reaction they give with iodine and sulphuric acid.—The cystoliths found in the species of *Morus* are hemispherical or spherical, and are provided with radiating fibres. Their lithocysts are situated on the upper side of the leaf, and are of large size.—In *Broussonetia papyrifera*, Vent. (Fig. 182, *D–E*) the large lithocysts on the upper side of the leaf show papillose differentiation; on the lower side hair-cystoliths are found. The large cystoliths on the upper side are sometimes produced by the fusion of two or three cystolith-rudiments.

The most essential points regarding the **hairy covering** have already been mentioned above. Unicellular bracket-hairs are present in *Dorstenia*, according to Kohl; in *Artocarpus* and *Cecropia*, according to A. Richter; and in *Broussonetia*, according to my own observation. The glandular hairs found in *Antiaris*, *Broussonetia* and *Morus* have a unicellular stalk and a more or less distinctly delimited ellipsoidal head, which is multicellular with transverse and longitudinal division-walls. Similar glandular hairs appear to occur also in *Cecropia* (Richter) and in some of the species of *Ficus*, at least on the young leaves (Meyer and Möbius); in *F. rubiginosa* glandular hairs have been found, consisting of a row of three cells, of which the terminal cell is long and tubular; '*F. indica*' has glandular hairs with a bicellular stalk and an elongated head, divided into two cells by a vertical wall (Möbius). The external glands of *Artocarpus* have a unicellular stalk and a disc-shaped head, divided by vertical walls; according to Haberlandt, these glands are hydathodes. The large pearl-glands of *Cecropia* and *Pourouma*, which were known to Meyen, remain to be described; it has been shown that in *Cecropia* they have a biological function as food-bodies. Several square centimetres on the lower surface of the base of the petiole in *Cecropia* and *Pourouma* are coated by a velvety brown covering of uniseriate hairs, amongst which the pearl-glands are situated; these glands look like insects' eggs; they fall off readily, but are continually replaced by others. They are ovoid or pear-shaped, and consist of numerous cells, which in *Cecropia* are rich in proteid-matter and fatty oil, according to Schimper; in this genus a stoma is situated at the apex of the gland. Glandular leaf-teeth having a similar structure to those of *Ulmus* (see above) are found for instance in *Morus* (Reinke).

According to Petit, the differentiation of the fibrovascular system in the **petiole** is not of a uniform type. In *Morus alba* the main system forms an arc; in species of *Ficus* and in *Castilloa elastica* a slightly interrupted ring, in *Broussonetia papyrifera*, *Maclura aurantiaca* and *Artocarpus integrifolia* a ring of 5–7 isolated vascular bundles, while in *Cecropia peltata* the petiole contains a still larger number of vascular bundles (about 30). For details see Petit, loc. cit.

The following statements may be made regarding the structure of the **wood**; they are based on my own examination of species of the genera *Sloetia*, *Morus*, *Conocephalus*, *Artocarpus* and *Ficus*, and also on the statements of Möller, Hesselbarth, Houlbert and A. Richter. The medullary rays vary in breadth; in *Conocephalus suaveolens*, Bl. and *Ficus indica*, L., they attain a breadth of seven cells even in herbarium-material. The size of the lumina of the vessels varies greatly; the perforations are simple. In contact with parenchyma the walls of the vessels as a rule bear bordered pits with transitions to large simple pits, but in *Sloetia Sideroxylon*, Teysm. et Binn. there are bordered pits only. Spiral thickening of the vessel-wall has been met with in species of *Morus* (chiefly in the vessels with narrow lumina), in *Broussonetia papyrifera*, Vent., and *Maclura aurantiaca*, Nutt. The wood-prosenchyma always bears simple pits and may have either wide or narrow lumina. According to De Bary, a gelatinous thickening-layer is present in the wood-fibres in

species of *Morus*, *Broussonetia* and *Ficus*; septation of the wood-fibres is found in species of *Ficus*. In many species of *Ficus*, in *Cecropia obtusa*, Tréc. and in species of *Artocarpus*, *Brosimum* and *Streblus* the wood-parenchyma forms tangential bands; this is also the case, though less distinct, in *Antiaris* and *Bagassa*.

The **pith** is homogeneous in *Ficus* (Mentovich).

The structure of the **cortex** has been specially examined by Möller in species of *Morus*, *Maclura*, *Ficus*, *Broussonetia*, *Artocarpus* and *Cecropia*, and by A. Richter in *Antiaris*. In these genera the cork arises in the outermost cell-layer of the cortex. The collenchyma of the primary cortex is developed in various ways. *Artocarpus* and *Cecropia* are characterized by extensive sclerosis of the primary cortex, accompanied by a certain amount of thickening. A ring of stone-cells, occurring in the primary cortex, is distinctive of *Morus alba*, L., according to Möller, and *Chlorophora tinctoria*, Gaud., *Cudrania javanensis*, Tréc. and *Streblus asper*, Lour., according to Engler. The pericycle includes isolated groups of bast-fibres, the individual fibres being often broad and flattened like a strap. The secondary bast contains bast-fibres, which vary in abundance and arrangement; in some cases (*Morus alba*, *Streblus asper*, according to Engler) the secondary bast-fibres, which are always distinguished by their considerable length, give rise to stratification of the bast. Some of the medullary rays of the bast are broad; the sieve-tubes have simple sieve-plates with coarse meshes.

4. Urticeae.

The Urticeae are characterized by the absence of laticiferous tubes and the frequent occurrence of independent cystoliths. Only one genus (*Neraudia*) is stated by Gaudichaud to exude a milky juice, but this genus has not yet been investigated anatomically [1]. The Urticeae have the following features in common with the rest of the Urticaceae: the lack of a uniform type of stoma; the usually superficial development of the cork; the simple perforations of the vessels; the simple pitting of the wood-prosenchyma; the long bast-fibres; and the excretion of oxalate of lime in the form of clustered and solitary crystals [2]. The hairy covering consists of simple unicellular clothing hairs, and small glandular hairs. As special forms of the clothing hairs we may mention the bracket-hairs (*Boehmeria*, according to Demeter, *Forskohlea*, according to Weddell), and the stinging hairs occurring in some genera, whilst the pearl-glands found in certain species of *Urtica* constitute a special form of glandular hair. The internal secretory elements [3] known to occur are lysigenous mucilage-canals in the pith and cortex of *Boehmeria platyphylla*, Don et Ham. and *Pipturus argenteus*, Hort. (Möller, Engler).

The **leaf-structure** has hitherto been little investigated. The stomata, which frequently occur on both sides of the leaf, have no special subsidiary cells in *Urtica* and some species of *Pilea*, while in other species of *Pilea*, and in the species of *Boehmeria*, *Elatostema* and *Pellionia* examined by Benecke there are three subsidiary cells. The thick fleshy leaves of *Pilea serpyllifolia*,

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[1] Chauveaud's statement (loc. cit., p. 119) regarding the occurrence of laticiferous tubes in the mature plant in *Urtica dioica* is incorrect, and is probably based on a remark made by Treub (Arch. néerl., 1879), who mentions 'laticifères' in *Urtica*. According to Gravis (loc. cit., p. 19) the elements referred to are merely bast-fibres having rather wide lumina in which contents are present.

[2] Schaarschmidt describes the occurrence of sphaerocrystals of a substance allied to hesperidin in alcohol material of *Urtica major*; according to Kallen nuclear crystalloids occur in the bristle-hairs of *Urtica dioica*.

[3] The tannin-cells described by Zopf (Bibl. bot., Heft 2, 1886, p. 23 and Tab. iii) in the stem of *Parietaria diffusa* are not distinct idioblasts.

Wedd. have stomata only on the upper side, where they occur in large numbers ; on the lower side the margin of the leaf bears hydathodes consisting of a group of water-pores with a subjacent epithema provided with the termination of a vein. Hydathodes having the same type of structure are also found scattered on the lower side of the leaf in *Pilea elegans*, and are similarly distributed on the upper side of the leaf in *Urtica urens* and *U. macrophylla*, Thunb. ; on older leaves of the last species the hydathodes are covered by small iridescent scales, composed of an organic substance, silica, and carbonate of lime. The lower epidermis of the leaf in *Pilea serpyllifolia* consists of water-storing cells of great height and with wide lumina. Hypoderm is stated by Pfitzer to occur in '*Urtica crassifolia*.'

The **cystoliths** of the Urticeae have been examined by Weddell. They are independent, i.e. they do not occur in connexion with the trichomes. As a rule they belong to the integumentary tissue, but they also occur in the pith, bast and primary cortex of the branch. They are usually spherical, ellipsoidal or fusiform (Fig. 183, *A*) ; other forms of rare occurrence are stellately branched (*Pilea stelluligera*, Wedd.). In those species which have fusiform cystoliths, others of irregular form are sometimes present in smaller numbers (e.g. bent

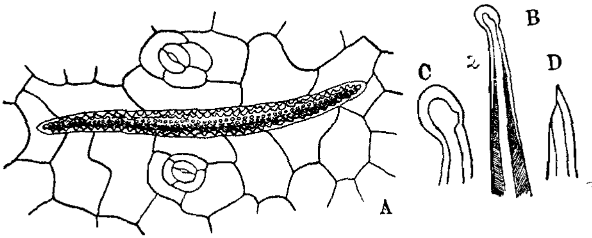

FIG. 183. A, Upper epidermis of the leaf of *Pilea serpyllifolia*, Wedd. with a cystolith. B–D, Stinging hair of *Urtica dioica*, L. : B, upper portion of the same ; the shaded part of the wall is calcified, the unshaded part silicified ; C, Tip of the stinging hair before, and D after the head has been broken off.—A Original, B after Kohl, C–D after Haberlandt.

like a horseshoe, &c.). The stalk of the cystolith is only slightly developed, or appears to be absent ; in many cases it probably becomes resorbed. In the fusiform cystoliths, which lie parallel to the surface of the organ, the stalk is attached to the middle of the cystolith. The latter sometimes shows concentric stratification and striation, and generally has a siliceous skeleton. In certain species of *Pilea* the body of the cystolith has been shown to be enveloped in a siliceous shell (Miliarikis), but this feature is not of systematic value.

In the dried leaf the cystoliths are generally visible, according to their different shapes, either as dots (cystolithi punctiformes) or as elongated, tubular or linear markings (cystolithi oblongi, fusiformes, lineares), or rarely (viz. in *Pilea stelluligera* mentioned above) as star-shaped bodies (cystolithi stellati). These and other features, which are likewise visible with a lens (e.g. the occurrence of the cystoliths on both sides, or only on one side of the leaf, the position of the cystoliths with reference to the veins, &c.), were employed for systematic purposes by Weddell in his monograph of the Urticeae ; in the first place he showed that independent cystoliths occur in almost all the genera included in his enumeration in De Candolle's Prodromus (excepting only *Laurea, Villebrunea, Debregeasia, Rousselia, Forskohlea* and *Didymodoxa* ; of these

Laurea is stated to possess no cystoliths, whilst the remaining genera have not yet been examined microscopically). The various forms of cystoliths are distributed in such a way amongst the different genera of Urticeae that the members of the sub-tribes Urereae, Boehmerieae, Parietarieae and Forskohleae have chiefly cystolithi punctiformes, while those of the sub-tribe Procrideae have for the most part cystolithi lineares.

Cystolithi punctiformes only are present in the following genera (arranged in the same order as in Weddell's work in DC. Prodr.): *Obetia, Laportea* (cystoliths small), *Scepocarpus* (cyst. very small), *Girardinia, Boehmeria* [1], *Chamabainia, Pouzolzia, Memorialis, Cypholophus, Touchardia, Sarcochlamys, Neraudia, Pipturus, Leucosyke, Maoutia, Phenax, Parietaria, Gesnouinia, Hemistylis, Droguetia* and *Distemon*. Cystolithi oblongi, lineares, fusiformes, &c., are found exclusively in the genera *Nanocnide, Fleurya, Achudemia, Lecanthus, Pellionia, Elatostema, Procris* (cyst. very small), *Helxine* and *Myriocarpa*; in *Myriocarpa* the linear cystoliths radiate from the bases of the hairs and thus produce a characteristic marking on the upper side of the leaf. Finally cystoliths of both forms are found within the limits of the following genera: *Urtica, Hesperocnide, Urera, Gyrotaenia, Pilea* (cyst. sometimes also star-shaped in this genus), *Poikilospermum* and *Australina*.

Regarding the **hairy covering**, the following statements may be added. The glandular hairs of *Boehmeria* and *Urtica* possess a unicellular stalk, and a head composed of a few cells. The pearl-glands found in *Urtica macrophylla, U. macrostachya* and *U. penduliflora* have a much more complicated structure, according to Meyen and Penzig. They are spherical emergences made up of an epidermis composed of small tabular cells with no stomata, and of a central mass consisting of a few large polygonal cells containing abundant protoplasm and no chlorophyll, but remarkably large quantities of a fatty body; the epidermal cells may sometimes grow out locally into hairs. Stinging hairs are described by Weddell as occurring in *Urtica, Hesperocnide, Fleurya, Laportea, Urera, Scepocarpus* and *Girardinia*. Those of *Urtica* and *Laportea* have been examined in detail by Haberlandt. Their structure, which is well known, is as follows: they are rather long, conical unicellular hairs, the apex bearing a small spherical or ovoid head, which is obliquely inserted, and readily breaks off, thus leading to the emission of the contents of the stinging hair. The hair is frequently seated on a multicellular pedestal, which surrounds its base like a cup, and is partly formed by the periblem. The nature of the wall of the stinging hairs is peculiar. The head and the neighbouring portions of the wall of the hair are silicified; in the latter (Fig. 183, *B*) the amount of silicification gradually decreases downwards, i.e. towards the base of the hair, this decrease in silicification being first shown by the innermost portions of the wall (i.e. those nearest the lumen of the hair); simultaneously with the decrease in silicification calcification begins, and ultimately near the base of the hair silicification is entirely replaced by the calcification. Regarding the unequal thickening of the wall of the head, and the characteristic line of fracture thus produced, &c., see Haberlandt and Fig. 183, *C–D*. Since the work of Gorup-Bessanez the irritant causing the stinging sensation has usually been stated to be formic acid; this, however, is incorrect, and it is probably a substance related to the ferments.

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[1] This opportunity may be taken of correcting an incorrect statement which has passed from one book to another. I refer to the fusiform cystoliths of a plant described as *Urtica macrophylla*, which De Bary figures in his 'Vergleichende Anatomie,' p. 112, Fig. 45; these cystoliths are reproduced by Engler in his revision of the Urticaceae (in the 'Natürl. Pflanzenfam.') under the synonymous name *Boehmeria platyphylla*, Don, and are also mentioned in Kohl's work (loc. cit., p. 127). The fusiform cystoliths in question do not belong to *Boehmeria platyphylla*, which like other species of *Boehmeria* has 'cystolithi punctiformes' only; the material investigated by De Bary was incorrectly determined.

The **petiole** contains isolated vascular bundles in the species investigated belonging to the genera *Urtica, Parietaria* and *Boehmeria* (Petit).

The structure of the wood and cortex have hitherto been little investigated. In the woody species the medullary rays of the **wood** are broad (*Urera sinuata,* Wedd., *Laportea canadensis,* Gaud.), or narrow (*Gesnouinia arborea,* Gaud., according to Engler). The herbaceous species usually have broad medullary rays, but in other cases (*Urtica dioica*) medullary rays are not present. Demeter and Herbst state that in species of *Boehmeria* the medullary rays are of exceptional height.

The vessels in *Urera* and *Laportea* are mostly isolated, and have rather wide lumina (diameter reaching ·08 mm.). In contact with other vessels they bear relatively large bordered pits (diameter of border = ·004–·007 mm.), while in contact with parenchyma transitions to simple pits are present. The perforations of the vessels are simple (even in *Boehmeria* and *Urtica*), and the wood-prosenchyma bears simple pits. The xylem of *Urtica dioica* includes groups of unlignified parenchyma.

The cork originates in the subepidermal layer of cells in *Pouzolzia* and *Boehmeria* (Möller), but at a considerable depth in the primary **cortex** in *Urtica dioica* (Gravis). The pericycle contains isolated groups of bast-fibres in *Pouzolzia, Boehmeria* and *Urtica*. The bast-fibres in *Urtica* attain a length of 77 mm.; their walls are silicified (Wicke).

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APPENDIX: TRIBE VIII, THELYGONEAE.

It is best to separate the monotypic genus *Thelygonum* from the Urticaceae as a distinct Order, as was done by Poulsen. This genus is essentially distinguished from the Urticaceae in its anatomy by the presence of bundles of raphides.

The structure of the **leaf** is bifacial. On both sides of the leaf the epidermis bears stomata, but on the upper side they are only present in small numbers. The stomata are accompanied on either side by one or more subsidiary cells, placed parallel to the pore. The upper epidermis of the leaf contains chlorophyll and tannin, and is composed of cells, which are not so strongly undulated as those of the lower epidermis. At the upper end of the petiole the fibrovascular system consists of isolated vascular bundles (Petit).

Poulsen makes the following statements regarding the strncture of the **stem**. The epidermis consists of small cells and bears unicellular hairs. The cortex contains no collenchyma, and is separated by a distinct endodermis from the pericycle and the vascular ring.

In addition to the unicellular trichomes just mentioned, colleters with a secretory palisade-like epidermis are met with on the young or ans of *Thelygonum* (Balicka-Iwanowska).

Literature: Petit, Pétiole, Act. Soc. Linn. de Bordeaux, t. 43, 1889, p. 16.—Poulsen, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 a, 1893, p. 123.—Balicka-Iwanowska, *Thelygonum Cynocrambe*, Flora 1897, pp. 365-6.

PLATANACEAE.

A whole series of anatomical features characterize this Order, which consists of the single genus *Platanus*. Of these we may mention: the simultaneous occurrence of simple and scalariform perforations, the latter with 1-12 bars; the broad primary medullary rays in the xylem and bast of the vascular ring; the bordered pitting of the wood-prosenchyma; the occurrence of sclerotic

parenchyma in place of secondary hard bast; the subepidermal origin of the cork; the absence of a special type of stoma; and the characteristic hairy covering, composed of candelabra-hairs, and accompanied by glandular hairs with unicellular glandular heads. Oxalate of lime occurs in the form of clustered and solitary crystals. Internal glands are absent.

The following statements may be made regarding the anatomy of the **leaf**. In the investigated species (e.g. *P. occidentalis*, L., *P. mexicana*, Moric., &c.) the leaves have centric structure. On both sides there is a single layer of palisade-tissue, the cells of which are considerably less elongated on the lower than on the upper side of the leaf. The vascular bundles of the larger **veins** are provided with a ring of sclerenchyma in *P. occidentalis*, L.; the smaller veins are vertically transcurrent on both sides by means of lignified tissue, having rather wide lumina, and extending as far as the epidermis. The guard-cells of the **stomata** lie on a somewhat higher level than the adjacent cells, the stoma being surrounded by a rather large number of these cells showing no special arrangement. In *P. occidentalis* stomata are also found in small numbers on the upper side of the leaf. A number of water-pores have been observed on the tips of the leaf-teeth in *P. occidentalis*. Oxalate of lime is excreted in the veins of the leaf, chiefly in the form of clustered crystals. The dense woolly covering of **hairs**, which is found on the young organs, but subsequently falls off (persistent on the lower side of the leaf in the South American species), is of a very peculiar type. It consists of candelabra-hairs, in which the main axis is formed by a row of cells, short at the base, but longer in the upper part of the trichome; at the points at which the transverse walls of this main axis are situated, whorls of 3–5 unicellular rays are inserted. The form of hair just described is the normal type, but numerous modifications occur; reduction in the branching is very common, especially in the hairs on the sepals and on the ovary, where one sometimes finds a certain number of simple uniseriate trichomes, composed of long cells and only provided with an occasional lateral branch. The peculiar hairy covering is also noteworthy from a hygienic standpoint, since, owing to the large numbers of these hairs falling off at the same time, they have an annoying inflammatory effect on the mucous membranes (for details see Morren and Drude). Besides these clothing hairs glandular hairs are also present. According to my investigations the glandular hairs situated on the surface of the leaf in *P. orientalis*, L. and *P. occidentalis*, L. consist of a short stalk-cell seated on the epidermis, and a spherical terminal cell. Niedenzu figures similar capitate glands with a rather long, uniseriate stalk in *P. occidentalis* var. *hispanica*, Wesmael. According to Hanstein the glandular hairs are sometimes (*P. acerifolia*) combined with the clothing hairs, some of the branches of the latter bearing glandular heads.

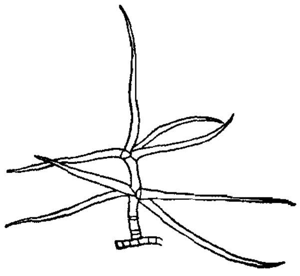

FIG. 184.—Candelabra-hair of *Platanus occidentalis*, L.—Original.

The structure of the **petiole** has been examined in detail by Petit in *Platanus occidentalis*. The course of the petiolar vascular system is very complicated; this is chiefly due to the well-known fact that the basal portion of the petiole has an internal conical cavity, and encloses the axillary bud. For details the reader is referred to the statements of Petit and Niedenzu, but the

following points may be mentioned here. A transverse section through the base of the petiole shows the central wide cavity (enclosing the axillary bud), while the wall of the latter contains a rather large number of vascular systems, some of which consist of rings of vascular bundles. At the apex of the petiole the fibrovascular system is composed of three arc-shaped or circular systems, placed one above the other. According to De Bary, only some of the vascular strands found in the stipules (viz. those in the two larger veins) are branches of the leaf-trace; the remaining vascular bundles of the stipules pass independently into the ring of bundles in the axis.

To the statements made above regarding the structure of the **wood**, we may add that the vessels have lumina of an average size of ·03–·04 mm., and that the wood-parenchyma is scantily developed.

The **pith** is homogeneous and consists of active cells with thick walls (Gris [1]).

We may now deal with the structure of the **cortex**. The pericycle contains massive groups of primary bast-fibres, united by stone-cells (having rather wide lumina) to form a composite and continuous ring of sclerenchyma, which is developed even in branches from herbarium-material (*P. occidentalis* and *P. orientalis*); the primary medullary rays of the cortex, which separate the groups of soft bast belonging to the individual vascular bundles from one another, also become sclerosed, even in thin branches; in the latter sclerosis is also to be seen in the primary cortical parenchyma. Subsequently sclerosis becomes still more general in the tissues of the cortex, and especially in those of the bast. The secondary cortex then exhibits stratification, broad layers of sclerotic parenchyma alternating with narrow bands of thick-walled, but unlignified parenchymatous cells, and narrow strands of sieve tubes (Möller). The sclerotic medullary rays of the cortex also penetrate in a characteristic manner into the medullary rays of the wood as short vertical ridges. The stone-cells never have greatly thickened walls or narrow lumina, but are distinguished by the relatively slight thickening of their walls. The cork has been shown to originate in the outermost cell-layer of the cortex in *P. orientalis* and *P. occidentalis*; its cells have thick walls and rather wide lumina. As is well known the formation of scale-bark subsequently takes place. The layer of cork cutting off a scale of bark is only a few layers of cells in thickness; its outer portion consists of thin-walled cells, its inner portion of cells with thick yellow walls; by the tearing of the thin-walled cells, the exfoliation of the scale of bark is brought about, while the thick-walled layer remains as a smooth covering for the living cortical tissue, until the next exfoliation takes place. Oxalate of lime is found in the cortex, chiefly in the form of solitary crystals.

Literature: Morren, Duvet du Platane, Bull. Acad. roy. de Bruxelles, t. iv, 1837, 8 pp. and Tab.—Hanstein, Harz- u. Schleimabs., Bot. Zeit. 1868, pp. 749–51 and Tab. xii.—Gris, Moelle, Nouv. Arch. Mus. d'hist. nat., t. vi, 1870, p. 267 and pl. xv.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, p. 33 and 329.—De Bary, Vergl. Anat., 1877.—Hesselbarth, Vergl. Anat. d. Holzes, Diss., Leipzig, 1879, pp. 57–8.—Möller, Rindenanat., 1882, pp. 85–7.—Solereder, Holzstr., 1885, p. 243.—Petit, Pétiole, Mém. Soc. sc. phys. de Bordeaux, sér. 3, t. iii, 1887, pp. 250–2 and pl. iii.—Drude, Haarfilz d. Platanenbl. etc., Gartenflora 1889, p. 393.—Ross, Periderma, Malpighia, vol. iv, 1890–1, p. 102.—Niedenzu, in Natürl. Pflanzenfam., iii. Teil, Abt. 2 a, 1891, pp. 137–8.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 154–6.—Virchow, Blattzähne, Arch. d. Pharm. 1896, p. 62.—Kuhla, Phelloderm, Bot. Centralbl. 1897, iii, p. 165.

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[1] I did not find the concentric bundles, stated by Niedenzu to occur at the periphery of the pith in *P. occidentalis* and *P. orientalis*. Possibly the structures interpreted as concentric medullary bundles by Niedenzu may be the protoxylem-groups of the vascular bundles together with the groups of sclerenchyma situated opposite them on the inner side.

LEITNERIEAE.

This Order consists of the single genus *Leitneria*, which in its anatomical features recalls the Dipterocarpeae and to some extent the Balsamifluae also; it has likewise been regarded as related to these two Orders on account of its exomorphic features. *Leitneria*, like the Balsamifluae and Dipterocarpeae, has secretory canals situated just at the margin of the pith; the structure of the secondary cortex is the same as in the Dipterocarpeae, viz. broad primary cortical medullary rays, which are enlarged outwards in the form of wedges, while the intervening portions of bast become correspondingly narrowed externally, and exhibit distinct stratification into hard and soft bast. The details of the anatomical features of *Leitneria floridana*, Chapm. are as follows:

In the interior of the branch there is a **pith** composed of isodiametric polygonal cells. At the margin of the pith the cells become smaller, and it is in this small-celled tissue that the **balsam-canals** run; they are situated in such close proximity to the primary xylem-groups of the vascular ring that Van Tieghem and Lecomte, who were the first to observe them, originally regarded them as belonging to the primary wood. A transverse section of the branch shows one or two dozen of these secretory canals, each lined by a single layer of epithelial cells, which project somewhat as papillae. The resin is yellow and brittle; it is insoluble in water, but readily soluble in alcohol. The wood is distinguished by its exceptional lightness and its spongy character, thus recalling the well-known Tupelo-wood; *Leitneria* inhabits the same marshy habitat as the plants from which this wood is derived (species of *Nyssa*). The medullary rays of the **wood** are narrow, being either one or two cells in breadth; none of the cells of the medullary rays are elongated to any considerable extent in the vertical direction. The vessels attain a diameter of ·05–·09 mm., and have simple perforations; in contact with one another they bear bordered pits, but in contact with parenchyma of the medullary rays they have large simple pits; these together sometimes resemble scalariform perforations. The wood-parenchyma is not abundant, and is only present in the neighbourhood of the vessels. The vessels are accompanied by tracheides with spirally thickened walls, whilst the ground-mass of the wood is composed of wood-fibres with wide lumina and simple pits. There are no secretory canals in the wood. The **cortex** is rich in tannin, and, like the wood, is devoid of resin-canals. In the secondary cortex, as stated above, the groups of bast belonging to the vascular ring become narrower outwards in the form of wedges, while the primary medullary rays between them become correspondingly broader outwards. The groups of phloem are stratified into hard and soft bast. The hard bast in *Leitneria* is composed of bast-fibres with very wide lumina, exceeding those of the elements of the bast-parenchmya; the pericyclic hard bast alone is composed of cells with thicker walls. The outer portion of the primary cortex is collenchymatous. Cortical vascular bundles are not present (a point of distinction from the Dipterocarpeae). The cork arises immediately beneath the epidermis, and consists of low cells.

The **leaf** of *Leitneria floridana* has bifacial structure. The stomata are not depressed. Beneath the upper epidermis of the leaf there is a hypoderm of several layers, containing clustered crystals; the latter, it may be added, are also met with in the pith and bast of the branch, and in the petiole. Two kinds of trichomes occur: viz. simple uniseriate hairs with an often bulbous base, two of these hairs being occasionally sunk in the epidermis side by side; and club-shaped glandular hairs, in which the biseriate stalk is only slightly marked off from the multicellular clavate head.

Three vascular bundles pass out from the branch into each leaf. They soon unite to form a ring, the secretory canals here also being situated at

the margin of the pith thus formed. In the leaf the secretory canals run in a similar position (on the upper side of the xylem), and are continued into the finest veins. There are no balsam-canals in the root.

In concluding the description of this Order we may add the following remark. The anomalous genus *Didymeles*, which is indigenous in Madagascar, and is referred to the Leitnerieae by Baillon, has no secretory canals, according to Lecomte and Van Tieghem; in the structure of its leaf (occurrence of sclerenchymatous fibres in the parenchyma of the petiole and in the mesophyll) *Didymeles* may perhaps be classed with the Ternstroemiaceae.

Literature: Van Tieghem et Lecomte, Struct. et aff. du *Leitneria*, Bull. Soc. bot. de France 1886, pp. 181-4.—Van Tieghem, in Journ. de bot. 1891, pp. 387-8.—Heim, *Leitneria*, Assoc. franç. p. l'avancem. des sc., Marseille, 1891, pp. 233-4, and Rech. s. les Diptérocarp., Thèse, 1892, p. 175 and pl. xi.—Trelease, *Leitneria floridana*, Report Missouri bot. Gard. 1894, 26 pp. and pl. 30-44.—Engler, in Natürl. Pflanzenfam., Nachtr. u. Reg. zu Teil ii-iv, 1897, p. 117.

JUGLANDEAE.

This Order is well characterized anatomically. One of the most distinctive features is the occurrence of peltate glands in all the species; the glands vary in size. The absence of resin-canals distinguishes this Order from the Anacardiaceae, with which an affinity has repeatedly been suggested. The following features are noteworthy: in the structure of the leaf, the stomata are surrounded by several ordinary epidermal cells exhibiting no special arrangement; in the structure of the wood, the medullary rays are not broad, the perforations of the vessels are mostly simple, and the wood-parenchyma is rather abundant; in the structure of the cortex, the development of periderm takes place superficially, isolated groups of primary hard bast are usually present in the pericycle (*Carya, Engelhardtia, Platycarya* and *Pterocarya*), or a composite sclerenchymatous ring occurs in the same position (*Juglans*), and secondary hard bast is abundant. Septation of the pith (without sclerosis), setting in at an early stage, is characteristic of the two very closely allied genera *Juglans* and *Pterocarya*. The hairy covering, apart from the peltate glands already mentioned, consists of simple unicellular hairs, a number of which are occasionally sunk side by side in the epidermis, thus forming tufted hairs. Oxalate of lime is found chiefly in the form of clustered crystals, but ordinary solitary crystals also occur.

I made a general comparative examination of the structure of the leaf and the hairy covering in *Juglans regia*, L., *Carya tomentosa*, Nutt., *Engelhardtia spicata*, Bl., *Platycarya strobilacea*, S. et Z. and *Pterocarya sorbifolia*, S. et Z. To the statements made above regarding the **stomata** we may add that stomata of two sizes frequently occur on the same leaf-surface, and that, in the species which I examined, the stomata are restricted to the lower side. In most cases **oxalate of lime** is only present in the leaf in the form of clustered crystals; the veins in *Platycarya strobilacea* alone contain solitary crystals besides numerous clustered crystals. In the mesophyll of *Platycarya strobilacea* large clustered crystals are present; and according to Radlkofer, the same is the case in *Carya porcina*, Nutt., where the crystals give rise to transparent dots. In all the species the **peltate glands** attain a moderate size; the short, unicellular or uniseriate stalk consists of cells with yellow walls; the shield has an entire margin and is composed of a varying number of ray-cells, which have thin walls, and become somewhat broader externally, in accordance with the form of the shield. In *Carya tomentosa* the large peltate glands are accompanied by others of smaller size but having the same structure;

Juglans regia and *Pterocarya sorbifolia*, besides having large glands, have others with a very small shield, divided into four cells by two vertical walls arranged as an orthogonal cross[1]. The glandular hairs in *Engelhardtia spicata* are accompanied by simple unicellular **hairs**, and in *Pterocarya sorbifolia* by (*a*) simple straight unicellular hairs, which have pointed apices, and a bulbous swollen base, and are provided with subsidiary cells, and (*b*) long narrow, somewhat curly unicellular trichomes with thick walls, a few of these hairs being sometimes sunk in the epidermis side by side; finally in *Carya tomentosa*, besides glandular hairs there are tufted hairs, composed of a group of stiff, unicellular, sclerenchymatous trichomes.

According to Petit, the basal portion of the **petiole** in *Juglans, Carya, Pterocarya* and *Platycarya* contains a closed fibrovascular system, triangular in outline. Higher up in the petiole vascular bundles branch off from this system, and in the characteristic region form a straight row of inversely orientated bundles, i.e. with bast above (*Juglans*), or one or more rings of wood and bast, on the upper side of the annular closed principal system. No sclerenchyma accompanies the fibrovascular system. According to C. de Candolle the petiole of *Engelhardtia* has a structure similar to that of *Juglans*, &c.

Fig. 185. Branch of *Pterocarya caucasica*, C. A. Mey., cut so as to show the septation of the pith.—Original.

The structure of the **wood** has been examined by me in numerous species of the five genera forming the Order. The medullary rays are narrow, from one to three cells in breadth; solitary or clustered crystals are sometimes (*Carya, Engelhardtia*) found in the medullary rays, and are contained in ellipsoidal and swollen, or in transversely septate cells. The vessels as a rule have simple perforations. Scalariform perforations with a rather small number of bars have only been observed in the primary wood in *Carya aquatica*, Nutt., and in relatively small numbers in the secondary wood in all investigated species of *Engelhardtia*. In contact with parenchyma the vessels bear simple pits, sometimes with transitions to bordered pits. The genus *Carya* is specially characterized by the thick walls of the pitted vessels (principally in the autumn wood), and the genus *Platycarya* by the spiral thickening of the walls of the pitted vessels and tracheides. Wood-parenchyma is abundant. The wood-prosenchyma bears simple pits in *Carya*, while in the remaining genera the pits have a distinct border, which is smaller than the pore.

The structure of the **cortex** has been examined by Möller in *Juglans regia*, L., *J. nigra*, L., *Carya alba*, Nutt., *C. amara*, Nutt., and by me in *Engelhardtia parvifolia*, C. DC., *Platycarya strobilacea*, S. et Z. and *Pterocarya rhoifolia*, S. et Z. The formation of cork takes place in the subepidermal cell-layer in *Carya, Juglans, Pterocarya* and *Engelhardtia*. The cells of the cork either have thin walls and rather wide lumina, or they have thick walls and are flat. The primary cortex is frequently collenchymatous, and often (e.g. *Pterocarya rhoifolia*) contains a very considerable number of clustered crystals, which are visible even with the naked eye, since they give a white colour to the transverse section. In all cases the pericycle contains massive groups of bast-fibres, which in *Juglans* are united by a small number of stone cells so as to form a ring. The medullary rays of the bast show considerable broadening towards

[1] The teeth on the margin of the leaf also have a glandular nature in some cases (*Juglans cinerea* and *Pterocarya*). They include the termination of a vein, mucilage-containing cells, and clustered crystals; and the apex of the tooth bears a few stomata (see Reinke, in Pringsheim's Jahrb., Bd. x, 1876, p. 167).

the exterior in *Engelhardtia* only, and in this genus the appearance of the bast in transverse section recalls that of the lime. Secondary hard bast is present in all cases, and sometimes gives rise to distinct stratification of the bast. The soft bast contains numerous clustered crystals; more rarely (*Juglans, Carya, Engelhardtia*) solitary crystals are also present, the latter showing a somewhat prismatic elongation in the bast of *Carya amara*. Regarding the structure of the **pith** it has already been pointed out above that septation of the pith without sclerosis occurs in *Juglans* and *Pterocarya* (Fig. 185) only. According to Gris, the diaphragms consist of cells which are generally empty or contain clustered crystals, while the peripheral portion of the pith is formed by active cells with thick walls. The non-septate pith of *Carya amara* is also heterogeneous.

Literature: Gris, Moëlle, Nouv. Arch. Mus. d'hist. nat., t. vi, 1870, pp. 277–8 and pl. xviii.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 94–6 and 390.—C. de Candolle, Anat. comp. de la feuille, Mém. Soc. phys. et hist. nat. de Genève 1879, p. 477 et seq.—Möller, Rindenanat., 1882, pp. 308–12.—Solereder, Holzstr., 1885, pp. 243–6.—O. Bachmann, Schildh., Flora 1886, sep. copy, pp. 17–18.—Radlkofer, in Sitz.-Ber. Münch. Akad. 1886, pp. 338–9.—Petit, Pétiole, Mém. Soc. sc. phys. et nat. de Bordeaux, sér. iii, t. 3, 1887, pp. 249–50 and pl. ii; and Act. Soc. Linn. de Bordeaux, t. 43, 1889, p. 12 and pl. ii.—J. E. Weiss, Korkbild., Denkschr. Regensburg. bot. Gesellsch. 1890, p. 54.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 156–64.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 (1894), p. 21.—F. Schneider, Esche, Forstl.-naturw. Zeitschr. 1896, p. 421 et seq.—Kuhla, Phelloderm, Bot. Centralbl. 1897, iii, p. 115.

MYRICACEAE.

The characteristic anatomical features of this Order, which includes the single genus *Myrica*, are as follows: large peltate glands; vertical transcurrence of the smaller veins in the leaf; absence of a characteristic stomatal apparatus; narrow medullary rays in the wood; tendency to form scalariform perforations in the vessels, which never have specially wide lumina; wood-prosenchyma with bordered pits; tendency to form a composite and continuous ring of sclerenchyma in the pericycle [1]; superficial formation of cork. Oxalate of lime occurs in the form of clustered and solitary crystals. Besides the peltate glands simple unicellular hairs are present.

The structure of the **leaf** in the species of *Myrica* has hitherto been little investigated. In *Myrica Gale*, L. I found it to be almost centric, owing to the palisade-like differentiation of the lowest layer of the spongy tissue; in *M. microcarpa*, Benth. the leaf-structure is bifacial. The stomata are found only on the lower surface of the leaf, and are surrounded by a number of adjacent cells. In *M. Gale* the cells of the lower epidermis are papillose, especially the cells adjoining the stomata. The vascular systems in the midrib are provided with arcs of sclerenchyma; in the smaller veins the vascular system is connected with both the upper and lower epidermis by special layers of elongated cells with wide lumina. In *Myrica Gale* clustered crystals are found in the veins of the leaf, in *M. microcarpa* clustered and solitary crystals, and also cells containing solitary crystals accompanied by small crystalline granules. The peltate glands consist of a uni- or biseriate stalk (the length of which varies according to the degree of depression of the gland in the surface of the leaf), and a shield, in which some of the ray-cells often do not reach the centre; the secretion is deposited beneath the cuticle. In *M. Gale* there are simple unicellular sclerenchymatous hairs in addition to the peltate glands.

The structure of the **wood** has been examined in 20 species. The maximum diameter of the vessels varies between ·02 and ·05 mm. In most species the vessels are isolated, and exhibit radial arrangement in *M. Gale* only. The perforations of the vessels, as already stated, show a tendency towards scalari-

[1] Engler's statement, that bast-fibres and stone-cells are absent in the Myricaceae, is incorrect, and is due to insufficient study of Möller's work.

form differentiation in all cases. In some species (*M. Faya*, Ait., *M. Gale*, L., *M. integrifolia*, Roxb., *M. javanica*, Bl., *M. mexicana*, Willd., *M. rubra*, S. et Z.) only scalariform perforations with 1-15 bars have been observed. All the other investigated species have simple (mostly elliptical, more rarely circular) perforations accompanied by others of the scalariform type; in these cases either the simple type is prevalent (e.g. in *M. aethiopica*, L. and *M. Burmannii*, E. Mey.), the scalariform perforations being almost confined to the neighbourhood of the primary wood, or the scalariform type is prevalent (e.g. in *M. ultera*, C. DC. and *M. cordifolia*, L.). The walls of the vessels are provided with bordered pits in contact with parenchyma. Wood-parenchyma is scantily developed. The medullary rays of the wood are narrow, at the most 4-seriate; the cells vary in height. The wood-prosenchyma has elements with lumina of varying size, and bears bordered pits on its walls.

In the structure of the **cortex** we may first mention that the cork originates immediately beneath the epidermis in *M. Gale* and *M. sapida*, Wall, according to my own observations, and in *M. californica*, Cham. et Schlecht. according to Möller. In the three species just mentioned the cells of the cork are sclerosed on one side only, viz. on the inner tangential walls. In *M. sapida* the primary cortex includes stone-cells, which have thick walls and narrow lumina, and are sometimes slightly branched. The pericycle contains isolated bundles of primary bast-fibres with intermediate stone-cells, so that either an interrupted (*M. Gale*) or a continuous (*M. sapida* and *M. californica*) composite sclerenchymatous ring is formed. In the bast of *M. sapida* there are elongated pitted cells, resembling sclerenchymatous fibres, and either occurring singly or arranged in small groups. The ends of the sieve-tubes bear several roundish sieve-fields arranged in a longitudinal row. Oxalate of lime is found in the axis in the form of solitary and clustered crystals. It remains to mention that Höhnel's statement regarding the occurrence of schizogenous resin-canals in the cortex of *M. sapida*, Wall. is incorrect. As will be seen from the description given above, I have examined this species and have found resin-canals to be absent, as in other members of the Order.

According to Gris, the **pith** in *Myrica Gale* consists of active cells with thick walls.

Literature: Gris, Moelle, Nouv. Arch. Mus. d'hist. nat., t. vi, 1870, p. 284.—De Bary, Vergl. Anat., 1877.—Hohnel, Holzer mit Harzg., Bot. Zeit. 1882, pp. 166-7.—Möller, Rindenanat., 1882, pp. 48-9.—Solereder, Holzstr., 1885, pp. 247-8.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 (1894), p. 27.

CASUARINEAE.

It is well known that the Casuarineae, which comprise the single genus *Casuarina*, are plants resembling horse-tails (*Equisetum*) in habit. As a result of the reduction of the foliar organs, abundant palisade-parenchyma is developed in the cortex of the young branches. The following additional features characterize the Casuarineae anatomically: the occurrence of cortical vascular bundles, which alternate with the bundles of the central cylinder, and, after running through the length of one internode in the cortex, pass into the central cylinder at the next node (Fig. 186 *A*); the structure of the wood, viz. (*a*) vessels having small lumina and simple or scalariform perforations, and bearing bordered pits in contact with parenchyma, (*b*) tangential bands of wood-parenchyma, (*c*) wood-prosenchyma with bordered pits, and (*d*) broad medullary rays; the peculiar origin of the periderm (see below), which is connected with the nature of the surface of the young branches; stomata, placed transversely to the longitudinal axis of the branch, and provided with parallel subsidiary cells (Fig. 186, *B*); finally, the occurrence of rows of tracheides on either side of the cortical vascular

bundles (Fig. 186, *C*). The hairy covering (Fig. 186, *D–E*) consists of simple or branched trichomes. Neither internal nor external glands are present. Oxalate of lime occurs in the form of clustered and ordinary solitary crystals.

In the following paragraphs we will first deal with the structure of the young branches, some of which in certain members of the Order exhibit no growth in thickness, and are subsequently thrown off like leaves; a description of the structure of the thick branches and stems will follow.

It should be borne in mind that the **young branches** of *Casuarina* consist of a row of joints or internodes, each of which is prolonged above into a short sheath, surrounding the base of the next higher internode, and terminating in 4–20 teeth. Coinciding with each of these teeth is a more or less strongly developed longitudinal rib, which runs down the sheath and the internode below it. Between the ribs there are corresponding longitudinal furrows of varying depth. The teeth of the sheaths alternate at successive nodes, and the same relation is exhibited by the ribs and furrows in the successive internodes.

First we will describe the structure of the young branch in *C. equisetifolia*, L. (Fig. 186, *A*); this description will be followed by a consideration of the points of difference presented by the other species. The internode in *C. equisetifolia* is distinguished by having furrows of considerable depth separated by proportionately high ribs; in a transverse section the ribs appear broad, the deep furrows very narrow. At the inner margin of the ribs, with which they correspond in position, the cortical vascular bundles are situated, while the bundles of the central cylinder, which alternate with the cortical bundles, lie opposite the furrows. We will now consider the structure of the transverse section, taking the tissues from without inwards. The nature of the epidermis varies according as it borders directly on the exterior, or forms the lateral surfaces of the longitudinal furrows. The peripheral portions of the epidermis, which form the external limit of the ribs, consist centrally of somewhat isodiametric cells polygonal in surface-view, but towards the furrows the cells become slightly elongated in the vertical direction. Stomata are not found in these portions of the epidermis, in which the outer wall is considerably thickened, and encloses small roundish doubly refractive bodies (not oxalate of lime according to my investigations, Fig. 186, *A* and *B*). The stomata are confined to those parts of the epidermis which line the longitudinal furrows. They are arranged (Fig. 186, *B*) in rows, and are placed transversely to the longitudinal axis of the branch. The stomata are provided with subsidiary cells lying parallel to the pore, and are situated between epidermal cells which are likewise elongated transversely to the longitudinal axis of the branch. Hairs spring from the base of the furrows (Fig. 186, *D–E*): in *C. equisetifolia* they are of two kinds, *viz.*: (*a*) simple trichomes, consisting of two short thin-walled basal cells, and a longer terminal cell with thicker walls (Fig. 186, *E*); and (*b*) branched trichomes of sympodial structure, having the form shown in Fig. 186, *D*. In other species or varieties the hairs have a different structure. Thus in *C. equisetifolia* var. *incana* Poisson figures hairs with two relatively short, superposed basal cells, above which, dichotomously inserted, are two longer cells forming an acute angle with one another; in some cases the dichotomous branching is repeated a second time. In the ribs of *C. equisetifolia* hypodermal parenchyma lies immediately beneath the epidermis, and is followed by one or more layers of hypoderm composed of sclerenchymatous fibres, which are elongated in the vertical direction, and are thus cut transversely in a transverse section of the branch. From the middle of this hypoderm a ridge of similarly arranged sclerenchymatous elements extends radially towards the bast of the cortical vascular bundle. The remaining portion of the rib is occupied by a number of layers of palisade parenchyma, the cells of which are elongated in a radial direction.

In those species which have branches destitute of furrows, or with only slight indications of them, the structure of the outer portion of the young branch is different. A few examples taken from Poisson's work may suffice. In *C. Chamaecyparis*, Poiss. the transverse section of the branch has a quadrangular outline, the four corners being produced into slight wings, and each containing subepidermal sclerenchyma, and a sclerenchymatous ridge extending towards the cortical vascular bundle; on the whole of the remaining circumferential portions of the branch, palisade-parenchyma is developed beneath the epidermis, except at four points, situated in the middle of the four lateral surfaces, where the internal

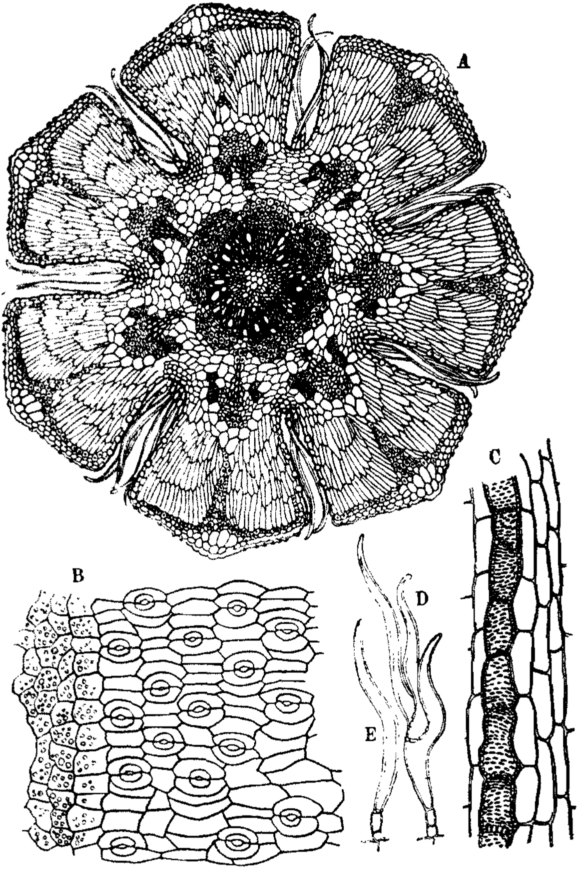

FIG. 186. *Casuarina equisetifolia*, L. A, Transverse section through a young stem (the crystals of oxalate of lime have been omitted for the sake of clearness; the bodies enclosed in the outer wall of the epidermis are shown as black dots). B, Epidermis from the lateral surface of a furrow of the branch; on the left, a portion of the epidermis, situated at the mouth of the furrow; it is devoid of stomata, and has warty prominences (drawn as circles), each of which corresponds to a body deposited in the outer wall (see A); on the right, a portion of the epidermis lying deeper in the furrow; this shows the characteristic stomata. C, A row of storage-tracheides in a longitudinal section; rows like this run on either side of the cortical vascular bundles (cf. A). D–E, Forms of hairs found in the furrows.—Original.

cortical parenchyma extends as far as the epidermis, which bears hairs at these points; stomata are developed on the lateral surfaces wherever palisade-parenchyma borders directly on the epidermis. In *C. leucodon*, Poiss. the transverse section of the branch is quite similar, except that the four corners are rounded off; hairs are entirely absent, and a subepidermal band of sclerenchyma is found in the middle of each of the lateral surfaces. Other species, such as *C. nodiflora*, Forst., *C. angulata*, Poiss. and *C. Deplancheana*, Poiss. var. *genuina* are essentially distinguished from *C. Chamaecyparis* and *C. leucodon* by the absence of the sclerenchymatous ridges connecting the subepidermal sclerenchyma with the cortical vascular bundles. In other respects the appearance of the transverse section in the first two of these species recalls that of *C. Chamaecyparis*, whilst in *C. Deplancheana* var. *genuina* it is more like that of *C. leucodon*. In *C. Deplancheana*, Poiss. var. *crassidens* the distribution of sclerenchyma and palisade-tissue in the branches is very peculiar. The branches have a rounded quadrangular outline in transverse section. The internal cortical parenchyma only extends up to the epidermis at four points, corresponding to the middle regions of the four lateral surfaces; everywhere else palisade-tissue is present beneath the epidermis, but is traversed by numerous radial sclerenchymatous ridges. Finally, Lecomte mentions that there is a continuous sheath of palisade-tissue beneath the epidermis in *C. Rumphiana*, Miq. The anatomical features, which have just been described, are of great value for the more special diagnosis of the Casuarineae, and a detailed examination of them from species to species is desirable; the results thus obtained will however only be of use if the exomorphic features are taken into consideration at the same time; not until this has been done will it be possible, for example, to determine whether the variety of *C. Deplancheana* characterized by the peculiar arrangement of the sclerenchyma is not best regarded as a distinct species, and so on. It may be added that Lecomte describes the occurrence of sclerenchymatous ridges in the ribs or corners of the branch in the following species: *C. Chamaecyparis*, Poiss., *C. Cunninghamiana*, Miq., *C. Decaisneana*, F. Müll., *C. Deplancheana*, Miq. var. *intermedia*, Poiss., *C. equisetifolia*, L. var. *incana*, A. Cunn., *C. leucodon*, Poiss., *C. oxyclada*, Miq., *C. quadrivalvis*, Labill.; but not in *C. angulata*, Poiss., *C. decussata*, Benth., *C. microstachya*, Miq., *C. nana*, Sieb., *C. nodiflora*, Forst. f., *C. sumatrana*, Jungh., *C. thuyoides*, Miq., *C. torulosa*, Ait.

The inner portion of the young branch in *C. equisetifolia* (cf. Fig. 186, *A*) up to the outer boundary of the central vascular cylinder consists of unlignified parenchyma with thin walls. This contains the cortical vascular bundles, which lie directly opposite the ribs, and are equal to them in number. They consist of a weakly developed mass of xylem situated on the inner side, and a phloem-group, directed outwards, and supported at its outer margin by a bundle of sclerenchymatous fibres. On the right and left of the phloem-groups rows of tracheides (Fig. 186, *A* and *C*) are situated. These tracheides are either of irregular shape, or almost isodiametric, or elongated like fibres, and their lignified walls bear simple pits of various forms. This system of water-storing elements unites the wood of the cortical vascular bundles with the palisade-tissue at certain points, and evidently serves for the supply of water to the latter tissue. The parenchymatous cortex is bounded towards the central cylinder by an endodermis. The vascular bundles of the central cylinder are separated by rather broad medullary rays, and at the outer margin of the masses of bast there are groups of sclerenchymatous fibres; these groups vary in size.

The structure of the **leaf-sheath** on the whole agrees with that of the outer portion of the cortex in the young branch. For information on this point, and also on the peculiar transverse bundles of fibres, which are present in the commissural portions of the sheath, and prevent tearing, see C. Müller and Morini.

The occurrence of **cortical bundles** is connected with the path followed by the vascular strands. The latter begin their course in the teeth of the leaf-sheaths, and run downwards in the ribs of the sheath; at the node they pass into the internode, and continue their course in the latter, running in the ribs, which are merely continuations of those on the sheath. At the next node they enter the inner ring of bundles, but first fuse with the leaf-traces which formed the inner vascular ring in the preceding internode. To accomplish this fusion each of the inner vascular bundles forks at the node into two short branches, each of which fuses with the nearest cortical bundle entering the inner ring.

The peculiar origin of the cork in the young branch also deserves notice; it has

been investigated by Sanio, Löw, Ross, Lecomte, and others. The phellogen first appears in the furrows, where it is subepidermal. In the ribs it develops on the inner side of the palisade-parenchyma, and according to Lecomte its position is outside the cortical vascular bundles in the basal portion of the internode, whilst further up it cuts through the middle of the cortical bundles, and at a still higher level it lies on the inner side of these bundles. In *C. torulosa* according to Sanio the cork, formed beneath the furrows, consists of cells which have their inner tangential walls strongly thickened, whilst on the inner side of the ribs there are at the most only indications of one-sided thickening in the cork-cells.

It now remains to consider the structure of the **thicker branches** and of the main stem. Numerous stone-cells are developed in the parenchymatous outer cortex as the branch increases in age; large numbers of stone-cells also arise between the groups of primary bast-fibres belonging to the vascular ring, and connect them so as to form a composite and continuous ring of sclerenchyma (*C. quadrivalvis*, Labill. according to Möller). In the young branches of *C. equisetifolia* only clustered crystals are found, occurring in the palisade-tissue, in the groups of bast, and in the parenchymatous outer cortex, but in older stems numerous solitary crystals are also present in the outer cortex. According to Möller's investigations the bast in *C. equisetifolia*, L. contains abundant sclerenchyma in the form of groups of bast-fibres and stone-cells, these being accompanied by numerous chambered fibres with solitary crystals. The inner portions of the primary cortical medullary rays also undergo considerable sclerosis, and in older stems penetrate the wood in the form of sclerenchymatous ridges. The sieve-tubes have sieve-fields showing scalariform arrangement. The following statements may be made regarding the structure of the wood. The vessels never have a large diameter (maximum diameter between ·015 and ·06 mm.), and are scattered in a transverse section. They have simple, mostly elliptical perforations, which, in all the species (14 in number) examined by Poisson and myself, are accompanied by scalariform perforations; the latter are at any rate present in the neighbourhood of the primary wood, and often also further out in the secondary wood. In some cases peculiar forms of scalariform perforations (some of them distorted forms) are found; they have been described in detail by Boodle and Worsdell. The walls of the vessels, even where they are in contact with parenchyma, are provided with bordered pits. Spiral or reticulate thickening of the pitted vessels is not uncommon (*C. humilis*, Link, *C. microstachya*, Miq., *C. nana*, Sieb., *C. paludosa*, Sieb., *C. stricta*, Ait.). Some of the medullary rays of the wood are distinguished by their breadth. In the herbarium-material of some species (*C. equisetifolia*, L., *C. Hügeliana*, Miq., *C. microstachya*, Miq.) I did not meet with specially broad medullary rays, but this does not necessarily mean that broad medullary rays are absent in these species, for it has been shown that the rays sometimes only broaden out in their outer portions, where they may ultimately attain a breadth of 24 cells or more. According to Goeppert the formation of new vascular bundles sometimes takes place in the broad medullary rays of the older wood in the same way as in *Clematis*. The wood-parenchyma forms tangential bands in the transverse section, and is very strongly developed. The wood-prosenchyma has thick walls, is sometimes distinguished by the presence of a gelatinous layer, and always bears bordered pits, though in varying numbers. In those species in which the pitted vessels were stated above to be spirally thickened, a similar thickening is also found on some of the elements of the wood-prosenchyma (except in the case of *C. stricta*).

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CUPULIFERAE.

1. Review of the Anatomical Features. The following anatomical features are common to the members of this Order: a tendency to form scalariform perforations in the vessels; wood-prosenchyma with bordered pits (with the single exception of *Nothofagus*); a composite and continuous, and in most cases permanently continuous, ring of sclerenchyma in the pericycle; subepidermal development of cork; stomata without special subsidiary cells; the occurrence of glandular hairs; the vertical transcurrence of the medium-sized veins in the leaf. A number of structural features in the axis are of value for the distinction of genera or groups of genera. Some of the medullary rays of the wood are very broad in the species of *Fagus* belonging to the section *Eufagus*, and in *Quercus*, but narrow, 1–4 cells thick, in the remaining members of the Order. The Tribes Betuleae (*Betula, Alnus*) and Coryleae (*Carpinus, Ostrya, Corylus*) are characterized by the radial arrangement of the vessels in the transverse section of the branch; in the Tribe Quercineae (*Quercus, Castanopsis, Castanea, Fagus*) this feature is more or less indistinct. There are only two genera, *Betula* and *Alnus*, which bear exclusively bordered pits on the walls of the vessels bordering on parenchyma of the medullary rays; in the remaining genera these portions of the walls are provided with large simple pits and bordered pits. Scalariform perforations are the only type present in the vessels in *Betula, Alnus, Corylus*, and *Distegocarpus Carpinus*, Sieb. et Zucc., while in *Ostrya, Fagus, Castanea, Castanopsis*, and *Quercus* both simple and scalariform perforations are found. In most of the Cupuliferae (species of *Carpinus, Ostrya, Corylus, Quercus, Castanea*) the secondary bast contains groups of bast-fibres; in *Betula, Alnus*, and *Fagus* they are replaced by groups of stone-cells. Hypoderm has only been observed in the leaf in certain species of *Alnus*. There are no special internal secretory elements, but many species are characterized by the presence of a mucilaginous epidermis in the leaf. Oxalate of lime is excreted in the form of clustered and solitary crystals; large, well-differentiated solitary crystals, occupying correspondingly large idioblasts in the mesophyll, give rise to transparent dots in the species of *Carpinus* (incl. *Distegocarpus*) and *Ostrya*. The hairy covering is formed by clothing and glandular hairs (Fig. 187). The clothing hairs are: (*a*) simple unicellular, or uniseriate (with thin transverse walls), generally sclerenchymatous trichomes; (*b*) tufted hairs (species of *Castanea* and *Quercus*); and (*c*) peltate hairs (species of *Castanea* and *Quercus*). The glandular hairs are of various shapes; glandular scales are found in the species of *Betula* and *Alnus*, and also in *Nothofagus*.

2. Structure of the Leaf. The leaf-structure has been examined in detail by Boubier in the Betuleae and Coryleae; my own investigations extended to *Betula alba*, L., *Alnus glutinosa*, Willd., *Carpinus Betulus*, L., *Ostrya carpinifolia*, Scop., *Corylus Avellana*, L., *Quercus Farnetto*, Ten., *Q. Ilex*, L., *Castanopsis indica*, A. DC., *Castanea vulgaris*, Lam., *Fagus* (*Eufagus*) *sylvatica*, L., and *F.* (*Nothofagus*) *antarctica*, Forst. The leaf-structure varies; it is either distinctly bifacial (e. g. in *Fagus antarctica*) or typically centric, the mesophyll consisting of palisade-parenchyma throughout its entire thickness (e. g. in *Quercus Ilex*) or only subcentric, the lowermost layer of the mesophyll being differentiated as palisade. Boubier found the mesophyll to have bifacial structure in all the Betuleae and Coryleae examined by him, with the single exception of *Ostrya carpinifolia*. The epidermal cells have straight or undulated lateral walls. Hypoderm has been met with on the upper side of the leaf in certain species of *Alnus* (*Alnus acuminata, A. elliptica,*

A. firma, A. glutinosa[1], *A. incana, A. Jorullensis, A. nepalensis, A. oblongifolia, A. pubescens,* and *A. rhombifolia*); it consists of a single layer, the component cells of which vary in size. The occurrence of a mucilaginous epidermis in the leaf is a far more frequent phenomenon. It has been observed: in all the species of *Betula* examined by Boubier (including *B. fruticosa,* contrary to Radlkofer's statement); in the genus *Alnus,* in *A. cordifolia, A. japonica, A. maritima, A. orientalis, A. rubra, A. serrulata,* and *A. viridis* (Boubier); in *Corylus americana* and *C. rostrata,* and in *Carpinus duinensis* and *C. japonica* (according to Boubier); but also in *Corylus Avellana, Quercus Farnetto, Q. pedunculata, Q. robur, Castanea vulgaris,* and *Fagus antarctica.* Similarly, some of the hypodermal cells in the species of *Alnus* cited above (except *A. firma,* and thus including *A. glutinosa*) also have mucilaginous inner membranes. Boubier mentions the formation of papillae in the lower epidermis of the leaf in *Betula corylifolia, B. nigra, Alnus nepalensis, A. oblongifolia,* and *A. pubescens,* the papillae being only slightly differentiated in the species of *Alnus.* The stomata are restricted to the lower side of the leaf in almost all the investigated species (exception: *Alnus orientalis*), and are always surrounded by several irregularly arranged epidermal cells. The larger **veins** of the leaf are provided with arcs of sclerenchyma; those of medium size are distinguished by the fact that they are vertically transcurrent, extending as far as the epidermis on both sides of the leaf by means of variously differentiated connecting tissue.

Oxalate of lime occurs in the leaf and axis in the form of clustered and solitary crystals, both forms being generally present in the same species, but exhibiting different distribution; the latter feature can only be employed for special diagnosis. Sanio (Monatsber. der Berliner Akad. 1857) mentions the occurrence of crystal-sand in the cortex in *Alnus glutinosa* and *Betula alba*; according to my own investigations, however, this is incorrect. In all the species of *Carpinus* (see Blenk) and in *Ostrya* (according to Boubier) the leaf-tissue includes idioblasts, which are filled with solitary crystals, and in both genera give rise to pellucid dots in the leaf.

The clothing **hairs** are simple unicellular or uniseriate trichomes, or stellate or peltate hairs. Simple unicellular hairs have been met with in species of *Betula, Alnus, Carpinus, Ostrya, Corylus, Castanopsis,* and *Fagus*; simple uniseriate hairs in species of *Alnus, Ostrya,* and *Corylus.* In *Corylus Avellana* and *Ostrya carpinifolia* the walls of the hairs exhibit a curious striation, which is connected with the internal structure of the wall. Stellate hairs have been shown to occur in *Castanea vulgaris, Quercus Farnetto,* and *Q. Ilex.* They consist of a tuft of sclerenchymatous cells (hairs), the whole group being either inserted directly in the epidermis, or seated on the apex of a short multiseriate pedestal developed from a group of epidermal cells. The peltate hairs (Fig. 187, *A*), which I examined in *Castanopsis chrysophylla,* A. DC., are allied to the stellate hairs; according to Prantl, they occur not only in species of *Castanopsis* but also in the species of *Quercus* belonging to the section *Pasania.* The peltate (glandular?) hairs of *Castanopsis chrysophylla,* are filled with yellow contents and consist of a low basal cell and a medium-sized shield with a slightly undulated margin; the ray-cells, only some of which reach the centre of the shield, have thin walls and exhibit secondary division-walls. Glandular hairs of various forms have been observed in the genera *Betula, Alnus, Carpinus, Ostrya, Corylus, Quercus, Castanea,* and *Fagus.* The two genera of the Betuleae (*Alnus* and *Betula*) are characterized by having glandular scales (Fig. 187, *B–D*). These possess (*a*) a short but broad stalk, which

[1] Walliczek's statement to the contrary (loc. cit., p. 236), viz. that *Alnus glutinosa* has a one-layered, partly mucilaginous epidermis, is incorrect.

usually projects into the shield, and is composed of several layers of low, suberized cells; and (*b*) a shield, the cells of which appear elongated like palisade-tissue in sections of the gland, and are mostly polygonal in surface-view. Similar glandular scales occur in *Fagus antarctica*, and probably also in other species of the section *Nothofagus*. The external glands found in the species of *Corylus* (Fig. 187, *E–F*) have a clavate shape; their basal portion is formed by a few rows of low, apparently suberized cells, whilst the upper, more or less swollen portion consists of a few thin-walled cells. According to Boubier, *Ostrya virginica* (Fig. 187, *G*), *Carpinus cordata*, and *C. Tschonoskii* have glandular hairs with a short uniseriate stalk composed of a few low cells, and a discoid flattened head consisting of a rather larger number of cells; *Carpinus Betulus* (Fig. 187, *H*), *C. caroliniana*, *Ostrya carpinifolia*, and *Castanea vulgaris* possess glandular hairs with a rather short, uniseriate stalk composed of a few cells, and a spherical or ellipsoidal head consisting of several cells exhibiting no

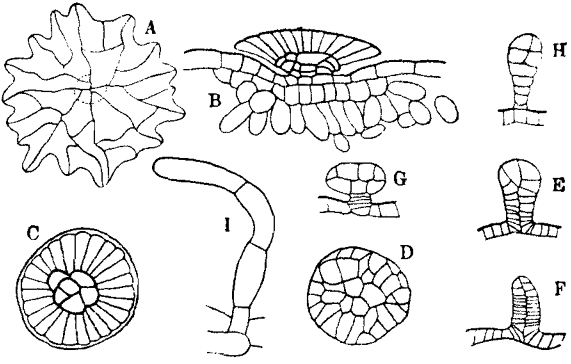

FIG. 187. A, *Castanopsis chrysophylla*, A. DC. B–D, Peltate glands of *Betula alba*, L.: B, in transverse section; C, glandular disc seen at a low, and D, at a high focus. E–F, *Corylus Avellana*. G, *Ostrya virginica*. H, *Carpinus Betulus*. I, *Quercus Farnetto*.—A–D and I original, E–H after Boubier.

special arrangement. Glands of the latter kind are also to be met with, though rarely, in *Quercus Farnetto*, where they accompany tubular, uniseriate external glands, which are curved in various ways (Fig. 187, *I*). Lastly, we may mention the rather large glands observed in *Corylus americana*, *C. ferox*, and *C. Avellana* (in the last of these species only on the petiole); they have a multiseriate stalk and a flattened spherical head composed of numerous cells. Having described the glandular hairs, we may make a few remarks on the glandular nature of the leaf-teeth, this subject having been investigated in species of *Alnus*, *Betula*, *Carpinus*, and *Corylus*. According to Reinke, the glandular character in *Alnus cordata* and *Betula alba* is due to glandular shaggy hairs with a structure similar to that of the glandular scales (i. e. they consist of a small amount of ground-tissue and a palisade-like epidermis), whilst in *Carpinus Betulus* and *Corylus Avellana* it is caused by glandular hairs similar in structure to those on the foliage-leaves. According to Hanstein, identical, or at any rate similar, glandular scales or hairs are also met with in *Alnus*, *Corylus*, *Carpinus*, and *Ostrya* as a protection to the buds.

The structure of the **petiole** has been examined by C. de Candolle and Petit, and more especially in the Betuleae and Coryleae by Boubier, and in *Quercus* by Bossebœuf and Pereira. Without discussing points of detail, which are of importance only for the diagnosis of species, we may note the following features as being useful in generic diagnosis; for other points the reader is referred to the works cited below. In all the genera of the Quercineae (*Quercus, Castanea, Castanopsis, Fagus*) the characteristic region of the petiole contains a closed annular fibrovascular system; according to Prantl, five vascular bundles pass out into the petiole in these genera. The genera *Alnus, Carpinus,* and *Corylus* agree in the structure of the characteristic region, the fibrovascular system forming in most cases a closed or almost closed ring of wood and bast, above which lies an arc of wood and bast (with the xylem directed upwards); the number of bundles in the initial region is three in *Corylus*, and usually three in *Alnus*, though from five to seven may be present. In the structure of the characteristic region the genera *Ostrya, Ostryopsis,* and *Betula* agree in as much as the vascular system in transverse section is open on the upper side, and has a lyrate or arc-like shape; there are three vascular bundles in the initial region in these genera.

3. STRUCTURE OF THE AXIS. The structure of the axis in the Cupuliferae has been thoroughly investigated. The following description is chiefly based on Möller's 'Rindenanatomie' and the statements in my 'Holzstruktur'[1].

The origin of the **cork** is the same in all cases, to judge from the concordant results of investigations carried out by Möller, J. E. Weiss, Douliot, and others, who examined numerous species of the genera *Betula, Alnus, Carpinus, Ostrya, Corylus, Quercus, Castanea,* and *Fagus*; the phellogen always arises in the outermost cell-layer of the primary cortex. The cells of the cork vary in their nature. The well-known white exfoliating cork (not bark) of the birch is distinguished by the presence of linear (transversely placed) lenticels; it is clearly differentiated from the fifth year onwards, and consists of alternating layers of tabular thick-walled cells and scarcely flattened thin-walled cells, the latter being filled with minute white granules (betulin[2]). In *Alnus* the cells of the cork, which is persistent for a long time in this genus also, are rather low and almost tabular. Amongst the Coryleae, *Ostrya* (*O. virginica*, Willd.) and *Corylus* (*C. Colurna*, L.) show a stratification of the cork similar to that found in *Betula*, layers of cells with wide lumina alternating with layers of tabular cells; in *Carpinus Betulus*, L., the cells of the cork are tabular and have thick walls. The species of *Quercus* have for the most part flat cork-cells with thick walls, while in *Fagus sylvatica* the cells have thin walls and are tabular, and in *Castanea vulgaris* they have thick walls, and are moderately flattened. The outer portion of the **primary cortex** is distinctly collenchymatous in all the members of the Order. Both clustered and solitary crystals may occur in the primary cortex. In *Alnus glutinosa* and *Ostrya virginica* large intercellular spaces are formed in the inner portion of the primary cortex in consequence of the tangential elongation of the cells and the separation of the walls in the tangential direction. The pericycle in axes not exceeding a certain thickness contains a composite and continuous ring of sclerenchyma in all investigated species. In most members of the Order this ring is retained during growth in thickness, and only in *Castanea vulgaris* and *Betula alba* does

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[1] The latter give the results of an investigation, which extended to all the species of all the genera of Cupuliferae represented in the Herbarium Monacense in the year 1884 (excluding *Ostryopsis*).

[2] With reference to betulin, besides other works, see Höhnel, Kork, etc., Sitz.-Ber. Wiener Akad., Bd. lxxvi, Abt. 1, 1877, and Merklin, in Mélanges biologiques St. Pétersb., iv, 1865, p. 565 et seq. According to Boubier, betulin does not occur in all the species of *Betula*, being absent in *B. Murithii* and *B. nigra*.

it undergo local rupture sooner or later. Groups of secondary bast-fibres have only been observed in the genera *Carpinus*, *Ostrya*, *Corylus*, *Quercus*, and *Castanea*, not in *Alnus*, *Betula*, and *Fagus*. They often give rise to a distinct stratification of the **secondary bast**. In *Alnus*, *Betula*, and *Fagus* groups of stone-cells are developed in place of the secondary bast-fibres, while in the secondary bast of *Quercus* similar groups of stone-cells accompany the groups of bast-fibres. A very peculiar feature is the sclerosis of the inner portions of the primary medullary rays in the cortex of *Fagus sylvatica* and certain species of oak, such as *Quercus Suber*; the sclerosed groups of cells, as in *Platanus*, form crest-like projections on the inner side of the cortex, penetrating the medullary rays of the wood, and thus establishing a firm dovetailing between the wood and the cortex.

The characteristic features in the structure of the **wood** have already been summarized above, but the following special points in the individual Tribes and genera may be mentioned. The genera *Alnus* and *Betula* (Betuleae) agree in almost all respects in the structure of the wood; they have: (*a*) narrow medullary rays, which are one or two, or at the most four cells in breadth, the cells being mostly elongated in the radial direction, and containing clustered crystals; (*b*) vessels, which have rather small lumina (diameter reaching ·04 mm.), and are arranged in radial rows, bear bordered pits in contact with parenchyma of the medullary rays, and have exclusively scalariform perforations with 5–30 bars; (*c*) a small amount of wood-parenchyma; and (*d*) wood-prosenchyma with wide lumina, and walls furnished with small but distinct bordered pits, the borders being smaller than the pits, which are not numerous. The different size of the bordered pits on the common walls of contact of the vessels serves to distinguish the two genera; for the diameter of the border is only ·0017 mm. in *Betula*, but ·003–·004 mm. in *Alnus*. The Coryleae (*Carpinus*, incl. *Distegocarpus*, *Ostrya*, and *Corylus*) show certain points of agreement with the Betuleae, viz. medullary rays, which are one or two, or at the most three cells in breadth; wood-prosenchyma with a constant type of structure (characterized by wide lumina, and small but not numerous bordered pits); and the always prevalent radial arrangement of the vessels, which have small lumina (maximum diameter = ·04 mm.). In other respects, however, there are a number of differences. The walls of contact between two vessels bear densely packed and rather large bordered pits, the borders being sometimes hexagonal owing to mutual contact. Where they border on the medullary rays the walls of the vessels are furnished with almost simple pits. Spiral thickening of the pitted vessels has been observed in *Carpinus Betulus*, L., *C. caroliniana*, Walt., *C. duinensis*, Scop., *C. viminea*, Lindl., *Distegocarpus laxiflora*, Sieb. et Zucc., *D. Carpinus*, Sieb. et Zucc., *Ostrya carpinifolia*, Scop., *O. virginica*, Willd., and *Corylus Colurna*, L. In all the investigated species of *Carpinus* and *Ostrya*, as well as in *Distegocarpus laxiflora*, the perforations of the vessels are for the most part simple and elliptical; only in the neighbourhood of the primary wood, and more rarely also at some points in the secondary wood, scalariform perforations with few bars are present. *Distegocarpus Carpinus* and all the investigated species of *Corylus*, on the other hand, have exclusively scalariform perforations with a varying number of bars (4–16). Wood-parenchyma is developed in greater abundance in the Coryleae than in the Betuleae, and sometimes forms tangential bands. Amongst the Quercineae the genus *Fagus* shows considerable diversity in the structure of the wood, and the differences agree with the splitting of the genus into two genera, *Nothofagus* and *Eufagus*, attempted by certain authors. Thus the species of *Eufagus* possess very broad medullary rays, which attain a breadth of eight cells even in the wood of the second year, whilst in the species of *Notho-*

fagus, which are indigenous in the antarctic regions of America and Australia, the rays are only from one to two cells broad; besides this difference we have the fact that the wood-fibres have bordered pits in *Eufagus* only, while in *Nothofagus* they bear simple pits, and are sometimes septate. In all the species of *Fagus* the vessels have smaller lumina than in the remaining genera of Quercineae; they also exhibit a more or less distinct radial arrangement. The perforations of the vessels are for the most part simple and elliptical, often elongated-elliptical, in outline; in all the species, however, scalariform perforations have also been observed: they have rather a small number of bars, and occur in the neighbourhood of the primary wood, sometimes also in the secondary wood. The walls of contact between the vessels bear numerous bordered pits, which occasionally show a scalariform arrangement; in contact with parenchyma of the medullary rays simple pits are present on the walls of the vessels. Spiral thickening of the walls is found in *Fagus australis*, Pöpp., and *F. procera*, Pöpp. Molisch met with deposits of carbonate of lime in the vessels of the heart-wood in *Fagus sylvatica*, and the same feature is found in *Betula alba*. Wood-parenchyma is scantily developed in *Fagus*. The structure of the wood in the two genera, *Castanea* and *Castanopsis*, belonging to the Quercineae, shows close agreement. Only narrow medullary rays, 1–3 cells broad, extend outwards from the four-rayed pith. The vessels are scattered in the transverse section of the branch, the radial arrangement of the vessels seen in most Cupuliferae being suppressed in this case. The perforations of the vessels are chiefly simple, and circular or elliptical; but, as in the other members of the Order having simple perforations, those of the scalariform type are to be found in the neighbourhood of the primary wood, and in some cases in the secondary wood also. In contact with parenchyma of the medullary rays the walls of the vessels bear simple pits. The wood-prosenchyma has bordered pits in *Castanea* and *Castanopsis*; the wood-parenchyma, which sometimes contains solitary crystals, is developed in abundance. The genus *Quercus* agrees with *Castanea* and *Castanopsis* in the following features: (*a*) the tendency to form scalariform perforations in the vessels; (*b*) the occurrence of simple and bordered pits on the walls of the vessels in contact with parenchyma of the medullary rays; (*c*) the bordered pitting of the wood-prosenchyma; (*d*) the abundant development of wood-parenchyma, which frequently contains crystals; and (*e*) the suppression of the radial arrangement of the vessels; it is distinguished from these genera, however, by the presence in the wood of broad medullary rays, extending outwards from a pith which is five-rayed in almost all cases (exceptions: *Quercus lappacea*, Roxb., and *Q. macrolepis*, Kotschy). Amongst the perforations of the vessels in the secondary wood of *Quercus*, those of the simple, elliptical or circular type invariably preponderate, but in all the species which I investigated (sixty-seven in number), and likewise in those examined by Abromeit, scalariform perforations were always present, if not in the secondary wood, at any rate in the neighbourhood of the primary wood. With regard to the grouping of the species of *Quercus* on the basis of the anatomy of the wood, see Abromeit.

The structure of the pith has been examined by Gris. *Alnus* and *Betula*, *Carpinus* and *Ostrya*, *Quercus*, *Fagus*, and *Castanea* have a homogeneous pith, whilst in *Corylus* alone it is heterogeneous. In *Corylus* the periphery of the pith is composed of active cells with rather thick walls, whilst the central portion consists of empty cells with rather wide lumina and thin walls. Regarding an abnormal occurrence of medullary vascular bundles with central phloem in *Alnus glutinosa* see Künkele.

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SALICINEAE.

The two genera of this Order, *Salix* and *Populus*, have the following anatomical characters in common: in the structure of the axis—superficial development of the periderm, isolated bundles of bast-fibres in the pericycle, stratification of the phloem into hard and soft bast, narrow medullary rays in the wood, simple perforations in the vessels, simple pits on the walls of the vessels where they are in contact with parenchyma of the medullary rays, wood-prosenchyma with simple pits and sometimes septate, and scantily developed wood-parenchyma; in the structure of the leaf—the tendency of the stomatal apparatus to differentiate in accordance with the Rubiaceous type, and the absence of glandular hairs. Oxalate of lime is excreted in the leaf and axis in the form of clustered and solitary crystals. Internal secretory organs are absent. The two genera of the Salicineae may be distinguished anatomically by the place of origin of the cork, in *Salix* it is the epidermis itself, in *Populus* the outermost cell-layer of the primary cortex.

I have examined the structure of the **leaf** in *Populus nigra*, L. and *Salix alba*, L. In both species the epidermis bears simple unicellular hairs, and stomata are present on the two sides of the leaf. In *Salix alba* the stomata are accompanied on either side by one or more subsidiary cells, placed parallel to the pore; whilst in *Populus nigra* this type of stoma is not always so well marked. The epidermis in many cases includes cells with mucilaginous inner walls, thus according to Radlkofer in *Salix acuminata*, *S. alba*, *S. aurita*, *S. Caprea*, *S. cinerea*, *S. daphnoides*, *S. fragilis*, *S. grandifolia*, *S. incana*, and *S. nigricans*, but not in *S. amygdalina*, *S. rubra*, *S. viminalis*, *Populus alba*, *P. nigra*, and *P. tremula*; occasionally (*S. alba* according to Walliczek) both the inner and outer wall of the same epidermal cell may be mucilaginous According to Rothert's abstract of Dobrowlianskij's work, hypoderm occurs beneath the upper epidermis in some members of the Order, and, in certain species of *Salix* belonging to the section Rugosae, the epidermal cells here and there show septation into two or three cells; the latter statement may possibly be due to an incorrect interpretation of the mucilaginous epidermal cells. According to Dobrowlianskij, the mesophyll varies in its structure. Very commonly the lowest cell-layer of this tissue contains little chloro-

phyll, and is differentiated like a hypoderm; according to my own observation this is also the case in *Populus nigra* and *Salix alba*. In these two species the remainder of the mesophyll consists of palisade-tissue; in other species dense or loose spongy tissue is present. Glandular hairs are *not* present in this Order. In place of them the leaf-teeth in certain species of *Salix* and *Populus* have a vesicular glandular structure, the glandular tissue being formed by the epidermis, the cells of which are transformed into long, narrow, radially arranged prisms[1].

In *Salix* and *Populus* three vascular bundles always pass into the **petiole**, and in both genera these bundles show a tendency to become rolled up into a circular form during their further course through the petiole. In the characteristic region we meet with a ring of wood and bast in *Salix*, and several superposed rings of vascular bundles in *Populus*. For details see C. de Candolle, Petit, and especially Komaroff.

I have examined the structure of the **wood** in *Populus tremula*, L., *P. nigra*, L., *Salix alba*, L., and *S. purpurea*, L. The medullary rays are narrow, being from one to two cells in breadth. According to Schulz, the medullary rays of the poplars consist entirely of cells of equal height, whilst those of the willows contain two kinds of cells, the one elongated in the vertical, the other in the radial direction. The vessels are scattered in the transverse section or are arranged in radial rows, several of them forming a row; their diameter attains ·066 mm. The perforations are simple. In contact with one another the vessels bear rather large bordered pits (diameter of the polygonal borders = ·004–·006 mm.), but in contact with parenchyma of the medullary rays there are simple pits of the size of the border in the bordered pits. Wood-parenchyma is scantily developed. The wood-prosenchyma, which has fairly thick walls and rather wide lumina, bears simple pits, and is sometimes (*S. alba*) septate.

The following statements regarding the structure of the **cortex** are chiefly based on Möller's work. According to Sanio, Möller, J. E. Weiss, and others, *the cork arises in the epidermis in the numerous investigated species of Salix*, but in the species of *Populus* it always develops in the sub-epidermal layer of cells. In *Populus* the cork-cambium first gives rise to several rows of cubical cells with wide lumina, and flattened cork-cells are not formed until later; in *Salix* a thin stratum of cork is formed each year consisting of a few layers of cells, which have their outer tangential walls sclerosed. The outer portion of the primary cortex is collenchymatous, and in certain species of *Populus* includes stone-cells, which sometimes (*P. alba*, L.) unite to form a ring. Isolated groups of bast-fibres are developed in the pericycle. Groups of hard bast are always present in the secondary bast, and they are often so arranged as to cause stratification of the phloem; in some cases (*P. alba*, L., *P. pyramidalis*, Roz.) groups of stone-cells occur as well. Oxalate of lime is found in the bast in the form of solitary and clustered crystals, the former being contained in chambered crystal-fibres, which sheathe the secondary bundles of hard bast; they are enclosed in the cell-wall. The medullary rays of the phloem traverse the secondary hard bast without becoming sclerosed.

The **pith** is heterogeneous according to Mentovich, the periphery being formed by active cells, the central portion by empty cells. In those portions of the stem of *Populus alba* and *Salix amygdalina*, in which the formation of heart-wood has already set in, the pith contains deposits of carbonate of lime (Molisch).

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[1] The buds of the poplar, which are covered with abundant balsam, exhibit a similar structure; the internal bud-scales have glandular surfaces, consisting of epidermal cells elongated like palisade, and covered by a thin cuticle (see Hanstein, loc. cit., and Areschoug, Acta Lund. 1870, tab. iv, 40).

Literature: Chalon, Tiges lign. dicotyl., 2e Mém., 1868, pp. 49–58.—Hanstein, *Harz- u. Schleimsbs.*, Bot. Zeit. 1868, p. 756.—Radlkofer, Monogr. *Serjania*, 1875, p. 103.—Möller, Holzanat., Denkschr. Wiener Akad. 1876, pp. 33–4 and 329.—Reinke, Sekretionsorg., Pringsheim Jahrb., Bd. x, 1876, p. 168.—Areschoug, Blad. anat., Minnesskr. Lund 1878, p. 57 et seq.—De Bary, Vergl. Anat. 1877.—C. de Candolle, in Mém. Soc. phys. et hist. nat. de Genève 1879, p. 446 et seq.—Molisch, Kohlens. Kalk, Sitz.-Ber. Wiener Akad., Bd. lxxxiv, Abt. 1, 1881, p. 7 et seq.—Möller, Rindenanat., 1882, pp. 89–95.—Schulz, Markstrahlgew., Diss., Berlin, 1882, pp. 18–19; also Jahrb. Berliner bot. Gart., Bd. ii.—Mentovich, Mark, Klausenburg, 1885, Hungarian; abstr. Just 1885, i, p. 787.—Solereder, Holzstr., 1885, p. 259.—Petit, Pétiole, Mém. Soc. sc. phys. et nat. de Bordeaux, sér. 3, t. iii, 1887, p. 246 and pl. ii–iii.—Dobrowlianskij, Vergl. Anat. d. Bl. d. S., Arb. St. Petersb. naturf. Gesellsch., Bd. xix, 1888 (Russian) pp. 161–70; abstr. by Rothert, in Bot. Centralbl. 1889, ii, p. 487.—Douliot, Périderme, Ann. sc. nat., sér. 7, t. x, 1889, pp. 330–1.—J. E. Weiss, Korkbild., Denkschr. Regensburg. bot. Gesellsch. 1890, sep. copy, p. 52.—Ross, Periderma, Malpighia, vol. iv, 1890, p. 104.—Strasburger, Leitungsbahnen, 1891, pp. 207–13.—Houlbert, Bois sec. dans les Apétales, Thèse, Paris, 1893, pp. 130–2.—Walliczek, Membranschleime, Pringsheim Jahrb., Bd. xxv, 1893, p. 238.—Pax, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 (1894), pp. 30–1.—Lazniewski, Biol. d. Alpenpfl., Diss., München, 1896, p. 40 et seq.; sep. copy from Flora 1896.—Virchow, Blattzähne, Arch. d. Pharm. 1896, sep. copy, pp. 51 and 61.—Komaroff, Struct. fol., Bull. Herb. Boissier 1897, pp. 226–46.—Kuhla, Phelloderm, Bot. Centralbl. 1897, iii, p. 116.—[Theorin, Om bladt. glandlerna hos en del Salices, Stockholm, 1882.—Soštarić, Bau d. Stammes d. S., abstr. in Oest. bot. Zeitschr. 1899, p. 117 (appears in Sitz.-Ber. Wiener Akad.).]

LACISTEMACEAE.

This small Order, which consists of the single genus *Lacistema*, is of uncertain systematic position, having been regarded by systematists as allied to the Piperaceae, Chloranthaceae, Urticaceae, and Samydaceae; it has neither the resin-cells of the Piperaceae and Chloranthaceae, nor the secretory cavities of the Samydaceae, nor the cystoliths of the Urticaceae. Its anatomical characteristics are: vessels with rather small lumina, and scalariform perforations; narrow medullary rays in the wood; wood-prosenchyma with few but distinctly bordered pits; a composite and continuous ring of sclerenchyma in the pericycle; superficial development of cork; and the absence of internal and external glands. Oxalate of lime is excreted in the form of clustered and solitary crystals. The trichomes are simple. Tannin is present in abundance in all parts of the plant.

I have examined the structure of the **leaf** in *Lacistema intermedium*, Schnizl., and *L. pubescens*, Mart. The leaves in these two species have typical bifacial structure, the spongy tissue being very lacunar. The stomata are restricted to the lower side of the leaf, and are surrounded by three or more epidermal cells, which in some cases show a certain degree of differentiation as subsidiary cells. The vascular bundles of the larger veins are accompanied by sclerenchyma. Clustered crystals are found in the mesophyll, and in the veins. The hairs are simple; they have rather thick walls, and are unicellular, or septate owing to the presence of delicate transverse walls; the basal portion of the hair is provided with rather large pits, elongated in the direction of the length of the hair.

I have examined the structure of the **axis** in *L. pubescens*, Mart., and *L. myricoides*, Sw. The following statements may be added to the data given above on this subject. The medullary rays of the wood are from one to two cells in breadth, and are chiefly composed of cells, which are elongated in the vertical direction. The vessels are quadrangular in transverse section, varying numbers of them being arranged in radial rows. The bordered pits on the walls of the vessels are small (diameter of border = ·002–·003 mm.), and are also found on the walls in contact with wood-parenchyma, or parenchyma of the medullary rays. The scalariform perforations have a varying number of bars; in *L. myricoides*, where the bars are rather broad, as many as twenty may be present. Wood-parenchyma is somewhat abundant. A few stone-cells sometimes occur in the primary cortex. The cork in *L. pubescens* arises

sub-epidermally, and includes cells having their walls more strongly thickened on one side (viz. the inner tangential and the contiguous portions of the radial walls). Oxalate of lime is found in the medullary rays of the wood in the form of ordinary solitary crystals.

Literature: Bokorny, Durchs. P., Flora, 1882, p. 371, sep. copy, p. 25.—Solereder, Holzstr., 1885, pp. 259-60.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 1 (1894), p. 15.

EMPETRACEAE.

This small Order, the members of which are distinguished by ericoid habit and by possessing rolled leaves, shows great uniformity in the anatomical structure of the vegetative organs. In illustration of this statement the following characters may be pointed out: the apparently bifacial structure of the leaf; the mucilaginous epidermis of the leaf; the absence of a special type of stoma; the very small lumina of the vessels; the tendency to form scalariform perforations in the vessels; the narrow medullary rays of the wood; wood-prosenchyma with bordered pits; the scanty development or

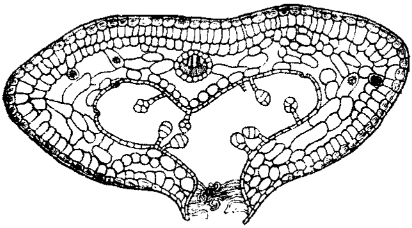

FIG. 188. Transverse section through the leaf of *Empetrum nigrum*, L.—Original.

complete absence of sclerenchyma in the cortex; the origin of the cork in the pericycle; the excretion of oxalate of lime in the form of clustered crystals or sphaerites; and the hairy covering, which is formed by simple unicellular trichomes, and short glandular hairs having a stalk composed of one or a few cells, and an ellipsoidal, uni- or multicellular head.

The structure of the **leaf** has been examined in all the four species of the Order (*Empetrum nigrum*, L. Fig. 188, *Corema album*, Don, *C. Conradii*, Torr., and *Ceratiola ericoides*, Michx.). The leaves of all the species belong to the category of rolled leaves, being deeply furrowed on the lower side. This furrow does not, as would appear at first sight, originate by the bending back of the margins of the leaf, but according to Gibelli and Gruber it is due to more rapid growth of the portions of the lower side of the leaf situated on either side of the midrib; in consequence of this, a groove first arises, but this subsequently becomes closed owing to the lateral extension of the more rapidly growing portions, and thus forms a central cavity. The epidermis, which limits the rolled leaf externally, is distinguished by having a strongly thickened outer wall, by the absence of stomata, and by the gelatinization of the inner cell-walls. The gelatinization has been correctly interpreted by Gruber and others only in the case of *Empetrum*[1], but according to my own

[1] The gelatinization is found both in the lowland, and in arctic and alpine specimens (see Wagner, Sitz.-Ber. Wiener Akad., Bd. ci, Abt. 1, 1892; Warming, Om Groenlands Vegetation, 1888; and Boergesen, Journal de Botanique, 1895, p. 3).

investigations it also occurs in the other three species, in which some of the mucilaginous inner walls (*Corema album* and *Ceratiola*) have a conical form and penetrate the leaf-tissue, while in some cases they also exhibit a number of unaltered cellulose-lamellae (e.g. in *Corema Conradii*). The epidermis lining the central cavity of the rolled leaf has thinner outer walls, and includes the stomata, the latter, according to Gibelli, being surrounded by several ordinary epidermal cells in *Empetrum*. The inner epidermis is also furnished with trichomes, which consist of glandular hairs and simple unicellular hairs. The former have a short unicellular or uniseriate stalk (in the latter case composed of a few cells), and an ellipsoidal head, which is unicellular, or divided into several cells, the division-walls being chiefly horizontal, one or two vertical walls being also present. The simple, unicellular hairs are so abundant in *Corema album* and *Ceratiola* that they form a tangled mass filling the entire cavity of the rolled leaf. In *Empetrum* and *Corema Conradii* they are chiefly present at the margin of the leaf, and those on the two margins become interlocked, thus firmly closing the aperture of the central cavity. Beneath the outer epidermis of the rolled leaf there is more or less typical palisade-parenchyma, whilst spongy tissue is situated above the epidermis, lining the central hollow, so that, if the course of development be disregarded, the leaf may be described as bifacial. There are no sclerenchymatous elements accompanying the vascular bundles of the veins. Internal secretory elements are likewise absent. Oxalate of lime is found in the leaf of *Empetrum* in the form of clustered crystals, and of beautiful sphaerites with radial striation and concentric stratification; in the leaf-tissue of *Corema album* oxalate of lime only occurs in the form of clustered crystals.

I have examined the **axis** in *Empetrum*, *Corema album*, and *Ceratiola ericoides*. In transverse section the wood (and this also applies to *Corema Conradii*) shows scattered vessels with small lumina (maximum diameter = ·024–·03 mm.), and narrow 1–2-seriate medullary rays, the cells of which are more or less elongated in the vertical direction. The perforations of the vessels are scalariform (with as many as ten bars) in *Empetrum*, whilst in *Corema* and *Ceratiola* they are, for the most part, simple and elliptical, more rarely scalariform. In contact with parenchyma of the medullary rays the walls of the vessels bear slit-shaped bordered or unbordered (?) pits. Wood-parenchyma is scantily developed; the wood-prosenchyma has distinct bordered pits. The following points are noteworthy in the cortex, etc. The epidermis, like the outer epidermis of the rolled leaf, has a very thick external wall. Sclerenchymatous fibres are rarely met with at the outer limit of the bast, being isolated in *Empetrum* according to Gibelli, and forming bundles at some points in *Ceratiola*. The first layer of periderm arises in the pericycle. In *Corema album* the cells of the cork are strongly thickened on one side (viz. on the inner tangential wall). Sclerenchymatous elements are entirely absent in the secondary bast. In *Ceratiola* the subepidermal cell-layer of the cortex has its inner tangential walls sclerosed, so that the cells appear thickened in the form of a horseshoe in transverse sections of the branch.

Literature: Gibelli, Strutt. delle foglie delle E., Nuov. Giorn. bot. Ital., vol. viii, 1876, pp. 49–60 and tav. v–vi.—Gruber, Anat. u. Entw. d. Bl. von *Empetrum*, Diss., Königsberg, 1882, 38 pp.—Solereder, Holzstr., 1882, p. 260.—Pax, in Natürl. Pflanzenfam., iii. Teil, Abt. 5, 1891, p. 124.—[Mac Ewan, Comp. anat. of *Corema*, etc., Bull. Torrey bot. Club, vol. xxi, 1894, pp. 277–85.]

CERATOPHYLLEAE.

There is little to be said regarding the anatomy of this interesting Order, which includes the single genus *Ceratophyllum* with about three species; it is well known that the members of this Order are submerged plants, having no

land-forms, producing no roots, and flowering and fruiting beneath the *surface of the water*. Features of special note are the complete absence of vessels and of stomata.

The **axis**, which, like the leaf, has been specially examined in *C. demersum*, L. by H. Schenck, has an epidermis containing chlorophyll, and devoid of stomata. Beneath the epidermis is the primary cortex, in which the outermost cell-layers are collenchymatous, while the inner portion contains a ring of air-spaces separated from one another by radial plates, one layer of cells in thickness. Numerous tannin-cells with suberized walls are present throughout the primary cortex. The vascular system of the stem is delimited from the primary cortex by a typical endodermis containing starch, and provided with Caspary's dots. The centre of the vascular strand is occupied by an axile air-canal, arising by the resorption of a small group of elements, but according to Caspary, Sanio, and Schleiden this group does not consist of tracheae (as is

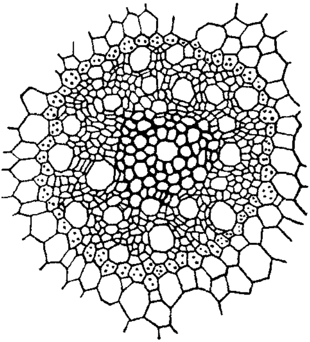

FIG. 180. Transverse section through the fibro-vascular system of *Ceratophyllum demersum*, L.—after H. Schenck.

the case in *Aldrovanda*, for example), but of procambial cells with narrow lumina and delicate walls. The axile canal is surrounded by an annular zone of collenchymatous, parenchymatous cells, which contain starch and are elongated in the vertical direction; as shown by H. Schenck, they are to be regarded as xylem (wood-parenchyma), though they include no vessels. From the xylem-portion a ring of phloem extends as far as the endodermis; this phloem consists of bast-parenchyma and sieve-tubes; the latter have wide lumina, are provided with companion cells, and are arranged in two rings in the transverse section. Vessels and lignification are thus entirely absent in the stem of *Ceratophyllum*.

According to H. Schenck, the segments of the **leaf** in *Ceratophyllum demersum* are elliptical or circular in transverse section, and are traversed by a vascular bundle, which runs nearer to the upper side, contains no vessels, and is surrounded by a parenchymatous sheath. The epidermis of the leaf is devoid of stomata, and consists of low cells, which are polygonal in surface-view, and contain chlorophyll. The latter is less abundant in the parenchyma of the leaf than in the epidermis. The mesophyll is not particularly strongly developed, and is traversed longitudinally by air-canals; of these three on

the lower side are large, and are separated from one another by septa of a single layer of cells, while on the upper side there are two much smaller canals. The parenchyma of the leaf, like that of the cortex, contains tannin-cells. The apices of the segments of the leaf in *Ceratophyllum*, as in those of *Myriophyllum*, are occupied by a long, shaggy, multiseriate glandular structure, the oily contents of which are rose-coloured in young stages and subsequently become rich in tannin. On either side of each of these glands there is a long, pointed unicellular hair. It has not yet been determined whether these peculiar glands, which subsequently disappear, serve for the protection of the young leaf-tips against parasites.

Regarding the relation of the axile strand in the stem to the leaf-trace strands, we may state on the authority of De Bary that *Ceratophyllum* is one of those plants in which the strands found in the stem are cauline, and have apical growth, whilst at the nodes branches pass off from the cauline strands into the leaves.

Literature: Schleiden, Kenntnis der C., Linnaea 1837, pp. 530–2.—Caspary, in Monatsber. Berliner Akad., 1862, p. 466.—Sanio, Endog. Gefässbündelbild., Bot. Zeit. 1864, p. 223.—Borodin, Blattsp. einig. Wasserpfl., Bot. Zeit. 1870, p. 850.—Magnus, Bemerk. z. Aufs. v. Borodin, Bot. Zeit. 1871, p. 482: here cited: Mercklin, Blattgest., Jena, 1846, pp. 72–7 and Tab. i; see also Hegelmaier, in Bot. Zeit. 1871, p. 501.—De Bary, Vergl. Anat. 1877.—Areschoug, Blad. anat., Minneskr., Lund, 1878, p. 144 et seq.—Klercker, Anat. et dével. de *Ceratophyllum*, Bihang K. Svenska Vet.-Akad. Handlingar, vol. ix, n. 10, 1885, 23 pp. and 3 Tab.: see also Bot. Centralbl. 1885, i, p. 157 et seq.—H. Schenck, Vergl. Anat. d. submers. Gew., Kassel, 1886, pp. 10–11 and 38, Tab. i and vi. – Dutailly, Glandes fol. des *Ceratophyllum*, etc., Assoc. franç. p. l'avancem. des sc., Paris, 1891, p. 220.—Engler, in Natürl. Pflanzenfam., iii. Teil, Abt. 2 (1894), p. 11.—Schilling, Schleimbild. d. Wasserpfl., Flora 1894, p. 327.

ADDENDA

RANUNCULACEAE (pp. 14-20).

1. THERE is little to add to the REVIEW OF ANATOMICAL FEATURES given in the earlier part of this book. Clustered crystals of oxalate of lime have also been observed in the petiole in species of *Thalictrum*, and in the leaf-sheath in *Anemone japonica*, S. et Z.; arm-palisade-cells have also been recorded in species of *Adonis*, *Clematis*, *Delphinium* and *Nigella*. The structure of the stem has been shown to be astelic in species of *Anemone*, *Caltha*, *Eranthis*, *Oxygraphis* and *Ranunculus* (incl. *Ficaria*).

2. STRUCTURE OF THE LEAF. Numerous details regarding the nature of the epidermis and the structure of the leaf are to be found in Goffart's work[1]. The stomata are confined to the lower side of the leaf in *Actaea*, *Anemone* pro parte, *Aquilegia*, *Delphinium* and *Trollius*, but occur on both sides in *Adonis*, *Anemone* pro parte, *Caltha*, *Ceratocephalus*, *Isopyrum*, *Myosurus* and *Nigella*. There is no arm-palisade-parenchyma (see also above) in *Hepatica* and *Pulsatilla*, while in *Aconitum columbianum*, according to Schwartz-Clements, it is only present in the shade-leaves. The clustered crystals of oxalate of lime, found in *Anemone* and *Thalictrum*, have already been referred to above. Sphaerocrystalline masses of unknown chemical composition have been observed in *Ranunculus aconitifolius*, L., *R. platanifolius*, L. and *R. sardous*, Crtz.; according to Schaffnit, similar deposits are present in the floral organs in species of *Ceratocephalus* and *Thalictrum*. The small club-shaped (see Fig. 1, *J*) or conical (see Fig. 1, *G*) trichomes have recently been shown to occur also in species of *Adonis*, *Anemone*, *Aquilegia*, *Delphinium*, *Isopyrum*, *Nigella* and *Trollius*, whilst longer tubular hairs with a basal ventricose swelling have been recorded for species of *Delphinium* and *Helleborus*. For information as to the number and course of the vascular bundles in the petiole, see especially Goffart and Ziegler; in *Paeonia* the bundles are less isolated than in the other genera.

3. STRUCTURE OF THE AXIS. According to Ziegler, anomalous structure of the stem is also found: (*a*) in *Delphinium Requieni*, in which numerous medullary vascular bundles are present in the lower part of the stem; and (*b*) in *Paeonia officinalis*, in which a single cortical concentric vascular bundle with central phloem is found in certain parts. According to the same author, *Thalictrum pyrrhocarpum* differs from other species of its genus in having no medullary bundles.

NOTE.—According to Stapf, an anomalous structure of the tuberous roots of *Aconitum* is characteristic of the Indian species, belonging to the sections *Anthora* (*A. rotundifolium*, Kar. et Kir., *A. heterophyllum*, Wall., *A. naviculare*, Stapf, *A. palmatum*, Hook. f., and probably also *A. Hookeri*, Stapf) and *Deinorrhizum* (*A. deinorrhizum*, Stapf and *A. Balfourii*, Stapf), and, according to Irmisch, Goris and A. Meyer, is also found in *A. Anthora*. In these species the parenchymatous ground-tissue of the central cylinder includes several vascular strands, for the most part con-

[1] In this treatise the following genera are dealt with: *Aconitum*, *Actaea*, *Adonis*, *Anemone*, *Aquilegia*, *Caltha*, *Ceratocephalus*, *Cimicifuga*, *Delphinium*, *Eranthis*, *Helleborus*, *Isopyrum*, *Myosurus*, *Nigella*, *Paeonia*, *Ranunculus*, *Thalictrum*, *Trollius*.

centric in structure, and each having a small pith of its own, and growing in thickness by means of a partial cambium; these strands are arranged in a circle in the transverse section, the outline of each strand being annular or stellate in the *Anthora*-type, but tangentially elongated (band-shaped) in the *Deinorrhizum*-type. Both on the outer and inner sides of this vascular system there are numerous phloem-bundles situated in the parenchymatous ground-tissue, and right at the centre there is a small indistinct pith. The mode of development of this anomaly has been determined by A. Meyer in *A. heterophyllum*. In the pith of the tuberous root, that is to say on the inner side of the normal vascular system, which grows in thickness by means of a normal cambium, a secondary meristem of circular outline in transverse section is developed; this meristem produces parenchyma and phloem-bundles on its inner side, and parenchyma, sometimes together with tracheae, on its outer side. This secondary cambial ring next becomes united at one point with the external (normal) cambium, and consequently in a transverse section it appears as though only one (the outer normal) cambium were present, though strongly invaginated at one point into the pith. In the further course of development the two cambia, i. e. the secondary meristem and the normal cambium, fuse at other points also, and in this way the concentric bundles mentioned above originate, each being surrounded by a partial cambium. It will be well to mention that according to Hartwich and Neuber the anomalous structure just described may sometimes also be met with in *A. Napellus*; in the tuberous roots of this species, moreover, other anomalies occur locally, but for these the reader must be referred to the literature, especially the works of A. Meyer, Hartwich, and Neuber. Regarding the retiform rhizomes and roots of *A. Lycoctonum* see ibid. and Jost, loc. cit.

For the structure of the root in the Ranunculaceae generally see also Lenfant, Mansion, Sterckx, ll. cc. The bulbils in the axils of the leaves of *Ranunculus Ficaria* are, we may add, formed mainly by a negatively geotropic root-structure, as shown by their anatomy.

Literature: Irmisch, *Aconitum Napellus*, Zeitschr. d. ges. Naturwiss., 1854, pp. 181–93 and Tab. iii–v.—Wasowicz, *Aconitum heterophyllum*, Archiv d. Pharm., 1879, i, p. 217 et seq.—A. Meyer, *Aconitum Napellus*, etc., Archiv d. Pharm., 1881, ii, pp. 240–76.—Langgaard, Japan. u. chin. Aconitknollen, Archiv d. Pharm., 1881, i, p. 161 et seq.—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 88 et seq.—Costantin, Tiges d. pl. aqu., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 et seq. and pl. 16.—Jost, Zerklüftung einiger Rhiz. etc., Bot. Zeit., 1890, p. 485 et seq. and Tab. vi.—[Miczinski, Anat. des Anémones hybrides, Compt. rend. Acad. Cracovie, xxiv, 1892, pp. 105–36 and pl. ii–iii.]—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894; abstr. in Just, 1894, i, p. 466, and Bot. Centralbl. Beih., 1894, p. 423.]—[Bastin, Struct. of *Cimicifuga*, Americ. Journ. Pharm. 1895, pp. 121–8.]—Borgesen, Arkt. pl. bladbygn., Bot. Tidsskrift, 1895, p. 219 et seq.—[Nihoul, Et. anat. des Ranunc., Mém. cour. et mém. d. savants étrang. Acad. d. Belgique. 1895.]—Ziegler, Gefassbundel im Stengel der Ranunc., Diss., Erlangen, 1895, 41 pp.—MacDougal, *Isopyrum occidentale*, Bot. Gaz. xxi, 1896, pp. 280–2.—Janczewski, *Anemone*, Revue de bot. 1897, p. 337 et seq. and pl. 18–19 (racine), and loc. cit. 1898, pp. 433 and 507 et seq. and pl. 16–19 (tige).—Lenfant, *Delphinium*, Arch. de l'Institut bot. de l'Univ. de Liège, i, 1897, 70 pp., pl. i–xi.—Mansion, *Thalictrum flavum*, ibid., 104 pp., pl. i–xiv.—Sterckx, Clématidées, ibid., 88 pp., pl. xv–xxix.—Spanjer, Wasserapparate. Bot. Zeit. 1898, i, p. 54.—Weinrowsky, Scheitelöffn. bei Wasserpfl., Diss., Berlin, 1898, p. 32.—Minden. Wassersec. Org., Bibl. bot., Heft 46, 1899, pp. 23 and 32.—[Collin, *Hydrastis canadensis*, Journ. de Pharm. et de Chimie 1900, p. 309; abstr. in Just 1900, ii, p. 16.]—Kliem, Veget. Regenerationsorg., Diss., Erlangen, 1900, p. 41.—[Resvoll, Nogle arkt. ranunklers morfologi og anatomi, Nyt. Magaz. for Naturvidenskab. 1900, 25 pp., pl. xii–xiv.]—Schleichert, Xerophyten der Muschelkalkh. bei Jena, Naturwiss. Wochenschr. 1900, p. 449 (*Anemone*).—Thomas, Feuilles sout., Thèse, Paris, 1900.—Goffart, Anat. des feuilles dans les Ranunc., Arch. de l'Institut bot. de l'Univ. de Liège, iii, 1901, 190 pp. and 14 pl., especially p. 150 et seq.—[Goris, *Aconitum*, Bull. Sc. pharmacol. 1901, no. 4; abstr. in Just, 1901, ii, p. 37.]—Petersen, Vedanatomi, 1901, p. 41.—Bouygues, Pétiole, Thèse, Paris, 1902, p. 10.—Mardner, Phan.-Vegetat. der Kerguelen, Diss., Basel, 1902, pp. 28–31 (*Ranunculus*).—Knothe, Unbenetzbare Blätter, Diss., Heidelberg, 1902, p. 16.—[Tschirch, *Helleborus*-Drogen, Schweizer. Wochenschr. f. Pharm. 1902, no. 35; abstr. in Just, 1902, ii, p. 68.]—[Vanderlinden, Alcal. et glycosides dans la famille des Ranunc., Recueil de l'Inst. bot. de Bruxelles, v, 1902, pp. 135–78; abstr. in Bot. Centralbl., xcii, p. 167.]—[Finlayson, Stem-structure of some leafless plants, Transact. and Proc. New Zealand Inst. 1903, p. 360 et seq. (*Clematis afoliata*).]—Schoute, Stelärtheorie, Jena and Groningen, 1903, pp. 112–15.—Theorin, Växttrichom., Arkiv för Bot. i, 1903, p. 171.—[Futo, *Hepatica transsilvanica*, Diss., Klausenburg, 1904, Hungarian.]—Freidenfeldt, Anat. Bau der Wurzel, Bibl. bot., Heft 61, 1904, pp. 45–54.—Neuber, Vergl. Anat. d. Wurzeln, Diss., Bern, 1904, pp. 5–52 (*Aconitum, Helleborus*).—Schaffnit, Nekt. der Ranunc., Diss., Erlangen, 1904.—Süssenguth, Behaarungsverh. der Würzburger Muschelkalkpfl., Diss., Würzburg, 1904, pp. 17–18.—Theorin, Växttrichom., Arkiv för Bot., iii, no. 5, 1904, p. 17.—[Clark

Cotyledon- and leaf-structure in certain Ranunc., Torreya, 1905, pp. 164–6.]—Sarton, Rech. expér. sur l'anat. des pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 1–25 (*Anemone, Ranunculus, Thalictrum*).—Schwartz-Clements, Relat. of leaf-structure to phys. factors, Trans. Americ. Microscop. Soc. 1905, p. 59, pl. vii, 3.—[Senft, Medizin. verw. Pfl. aus der Fam. d. Ranunc., Pharm. Praxis, 1905, no. 1 et seq.; abstr. in Bot. Centralbl., cii, p. 268.]—Stapf, Aconites of India, Annals Bot. Gard. Calcutta, x, 2, 1905, pp. 126–30.—Géneau de Lamarlière, Membr. cut. d. pl. aqu., Revue de bot. 1906, p. 289 et seq.—Piccioli, Legnami, Boll. Siena, 1906, p. 132. [For additional literature see p. 1171.]

DILLENIACEAE (pp. 20–24).

2. Structure of the Leaf. In certain species of *Wormia* a hypoderm composed of large cells is found beneath the upper epidermis, while in *Dillenia indica*, L. there is a single layer of hypoderm.

3. Structure of the Axis. The wood in *Wormia ferruginea*, Baill. consists of: (*a*) broad medullary rays reaching a breadth of ten cells; (*b*) vessels with exclusively scalariform perforations (with as many as forty bars), and bearing bordered pits in contact with wood-parenchyma; and (*c*) wood-prosenchyma having bordered pits (Ursprung). A composite and continuous ring of sclerenchyma in the pericycle is also present in the young axis of *Dillenia ochreata* (= *Wormia ochreata*) and *Doliocarpus semidentatus* (Pitard).

Literature: Ursprung, Anat. u. Jahresringbild. trop. Holzarten, Diss., Basel, 1900, pp. 10–13 (*Wormia ferruginea*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 83.—Fabricius, Laubblattanat., etc., Beih. Bot. Centralbl., xii, 1902, pp. 310, 311.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 333 (*Dillenia*).—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handling. 39, n. 2, 1905, pp. 12–15 and Tab. xxiv–v (*Dillenia*), and pp. 105–6 (*Tetracera*).—[Moll and Janssonius, Mikrographie d. Holzes, Leiden, 1906, pp. 65–80 (*Wormia, Dillenia*).]

CALYCANTHACEAE (pp. 25–27).

1. The statement in the Review of Anatomical Features regarding the absence of a sclerenchymatous ring in the pericycle requires some modification, since according to Van Tieghem (see also Pitard, loc. cit.) the lower internodes in *Chimonanthus* contain a composite and continuous sclerenchymatous ring composed of groups of bast-fibres and stone-cells with U-shaped thickenings; in *Calycanthus*, on the other hand, there are invariably isolated groups of bast-fibres. The stone-cells with U-shaped thickenings afford an important diagnostic character of the Order, since they also occur in *Calycanthus*.

3. Structure of the Axis. According to Van Tieghem the anomalous structure of the axis (occurrence of four cortical vascular bundles with inversely orientated wood and bast) is not the same in the two genera belonging to the Order. In *Chimonanthus* the normal vascular ring (stele) has a quadrangular outline, and the primary cortex is normal; the cortical vascular bundles lie in the parenchymatous pericycle on the inner side of strongly developed groups of pericyclic fibres; the cortical 'bundles' actually consist of two strands. In *Calycanthus*, on the other hand, the stele is cylindrical, but the primary cortex has thickened angles; the vascular bundles, which here consist only of a single strand, lie in the inner portion of the primary cortex.

Literature: Lloyd Williams, Sieve tubes of *Calycanthus occidentalis*, Ann. of Bot., viii, 1894, pp. 367–70.—Biermann, Ölzellen, Diss., Bern, 1898, pp. 58, 59.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 83.—Van Tieghem, Tige des Calycanth., Ann. sc. nat., sér. 8, t. xix, 1904, pp. 305–20; also Bull. Mus. d'hist. nat. 1904, p. 68 et seq.—Van Tieghem, Méristèles corticales, Ann. sc. nat., sér. 9, t. i, 1905, p. 40.

MAGNOLIACEAE (pp. 27–31).

1. In the Review of Anatomical Features the following additions or modifications are necessary. The clothing hairs are mostly multicellular and uniseriate; in some cases (species of *Magnolia* and *Michelia*) they are uni-

cellular. Tufted hairs with 1–2-celled rays are found in ***Magnolia fasciculata***, Parm. The statement as to the absence of a sclerenchymatous ring in the pericycle is incorrect, for not uncommonly there is a continuous or interrupted composite ring of sclerenchyma in place of the isolated groups of bast-fibres. The genus ***Zygogynum*** agrees with *Drimys* in having no vessels, and in the structure of the wood resembling that of the Coniferae.

2. STRUCTURE OF THE LEAF. Papillose differentiation of the lower epidermis is also found in *Magnolia ferruginea*, Parm. and in *Drimys retorta*, Miers, but not in *D. granatensis*, Mut., as was incorrectly stated on p. 28. A continuous one-layered hypoderm on the upper side of the leaf has also been demonstrated in *Magnolia Campbelli*, Hook. f. et Thoms., *M. fasciculata*, Parm., *M. ovata*, Parm., *M. xerophila*, Parm., *Talauma inflata*, Parm., *Michelia calcuttensis*, Parm., *M. Kisopa*, Buch.-Ham., *M. montana*, Bl., *M. ovalifolia*, Wight, *Manglietia insignis*, Bl., *M. pilosa*, Parm., *Drimys brasiliensis*, Miers and *D. granatensis*, Mut.

Secretory cells are also present in the mesophyll and in the cortex in *Zygogynum*. According to Parmentier, the secretory organs, described as mucilaginous cells by Blenk, 'Lacunes à gomme' by Vesque, resiniferous intercellular spaces by D'Ippolito, and 'Canaux gummifères' by Parmentier, are found quite generally in the Schizandreae in the bast of the larger veins of the leaf.

Branched sclerenchyma-cells also occur in the mesophyll, though this is exceptional, e.g. in the spongy tissue in *Drimys retorta*, Miers. In certain species of *Zygogynum* stone-cells have been observed in the mesophyll, whilst in certain species of *Drimys* and *Zygogynum* there are zones of more strongly thickened and lignified mesophyll-cells.

Special mention should also be made of the occurrence of clustered crystals in the epidermal cells in a new species named *Magnolia echinina* by Parmentier.

3. STRUCTURE OF THE AXIS. With reference to the structure of the pith, we may add that incomplete diaphragms composed of stone-cells occur in *Drimys Howeana*, F. v. Müll., and that stone-cells, isolated or in groups, are not uncommonly found in the Wintereae.

Wood resembling that of the Conifers in structure has recently been demonstrated by Van Tieghem in almost all the known species of *Drimys* [1] (with the single exception of *D. uniflora*, Turcz, which he was unable to examine), and by me and Van Tieghem in *Zygogynum*. A certain number of the species are further characterized by the presence of scalariform bordered pits on the tracheids of the spring-wood. The exceptions quoted by Parmentier, viz. *Drimys Mülleri* and *D. vascularis*, both of which possess vessels in the wood, are certainly not members of the genus *Drimys*.

In the development of the cork the phellogen, according to Parmentier, arises quite generally in the subepidermal layer of cells in species of *Magnolia*, *Talauma*, *Michelia*, *Manglietia*, *Liriodendron*, *Illicium*, *Drimys* and *Schizandra*. According to Van Tieghem and Douliot, however, the cork in *Drimys* develops in the epidermis (and not subepidermally). The pericycle contains either

[1] It may be mentioned here that owing to the peculiar structure of the wood Van Tieghem unites the genus *Drimys*, which he moreover subdivides into five genera (*Drimys*, *Wintera*, *Bubbia*, *Belliolum*, and *Exospermum*), with *Zygogynum*, as well as *Trochodendron* and *Tetracentron* (see the note under Trochodendraceae) to form a special taxonomic group, the Homoxylées, as opposed to the rest of the Dicotyledons (Heteroxylées).

It may also be pointed out that D'Ippolito's statement to the effect that tracheids only and no vessels are present, at any rate in the later growth of the wood, in species of *Illicium*, *Liriodendron*, *Magnolia*, *Michelia*, and *Talauma*, is without doubt incorrect. I have recently examined the wood from thick pieces of the stem of *Liriodendron tulipifera* and *Magnolia grandiflora*, and have met with vessels having characteristic scalariform perforations.

a composite and continuous sclerenchymatous ring (*Magnolia* pro parte, *Talauma*, *Michelia* pro parte, *Drimys* pro parte), or isolated groups of bast-fibres (*Magnolia* pro parte, *Michelia* pro parte, *Manglietia*, *Liriodendron*, *Illicium*, *Drimys* pro parte, *Schizandra*, *Kadsura*, *Zygogynum*), between which there are sometimes groups of stone-cells, so that an interrupted and composite mechanical ring is formed. For further details regarding the differentiation of the sclerenchymatous ring in *Magnolia* and *Talauma* see also Pitard, loc. cit. Secondary hard bast showing varied differentiation is also present in species of *Talauma*, *Michelia*, *Manglietia*, *Illicium* and *Drimys*, while in the Schizandreae the bast includes only the crystal-sclerenchyma, described on p. 29; similar elements may also occur in the primary cortex and in the pith [1].

Literature: Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 36-40.—Brandt, Wenig bek. Rinden, Diss., Dorpat, 1894, p. 21 et seq.—[Matsuda, Anatomy of Magnol., Journ. Coll. Sc. Imp. Univ. Japan, vi, 1894, p. 115 et seq.]—Parmentier, Hist. d. Magnol., in Giard, Bull. scientif. de la France et de la Belgique 27, 1896, pp. 159-337 and pl. viii-xi.—Biermann, Ölzellen, Diss., Bern, 1898, pp. 44-7.—Solereder, *Cercidiphyllum*, Ber. deutsch. bot. Gesellsch. 1899, pp. 396, 397.—Van Tieghem, Homoxylées, Journ. de bot. 1900, separate copy, 68 pp.—D'Ippolito, Caule delle Magnol., Malpighia, xv, 1901, pp. 438-60.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 103, 104.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 294 (*Talauma*).—Simon, Wintergrüne Gew., Ber. deutsch. bot. Gesellsch. 1902, p. 241.—Strasburger, *Drimys Winteri*, Flora, 1905, Ergänz.-Bd., pp. 217, 218.—[Moll and Janssonius, Mikrographie des Holzes, Leiden, 1906, pp. 80-106 (*Talauma*, *Magnolia*, *Manglietia*, *Michelia*).]—Piccioli, Legnami, Bull. Siena, 1906, pp. 127 and 148.—[Holtermann, Einfluss d. Klimas, 1907, p. 117 (*Michelia*).]

TROCHODENDRACEAE (pp. 31-34)[2].

1. To the statements made in the REVIEW OF ANATOMICAL FEATURES the following additions are necessary. In *Euptelea* simple uniseriate clothing hairs generally occur on the young leaf; these hairs consist of: (*a*) a basal cell, or several short basal cells, showing local biseriate arrangement; and (*b*) one or several, more elongated, terminal cells with wide lumina. Arm-palisade parenchyma is present in *Euptelea polyandra*, S. et Z. and *E. pleiosperma*, Hook. f. et Th.

2. STRUCTURE OF THE LEAF. The lower epidermis in the leaf of *Euptelea pleiosperma*, like that of certain other members of the Order, shows papillose differentiation.

The caoutchouc-cells in the leaf of *Eucommia* are generally found in the veins (in the bast of the vascular bundles, and in the ground-tissue), but they sometimes also penetrate into the mesophyll, where they ultimately terminate with swollen ends. In the root of *Eucommia* these caoutchouc-cells are present in the bast and in the neighbouring pericyclic region.

3. STRUCTURE OF THE AXIS. Subepidermal development of the cork is also found in *Trochodendron* and *Tetracentron*.

Literature: Parmentier, in Giard, Bull. scient. de la France et de la Belgique 27, 1896, p. 318 et seq.—Solereder, *Cercidiphyllum*, Ber. deutsch. bot. Gesellsch. 1899, pp. 400, 401.—Van Tieghem, Homoxylées, Journ. de bot. 1900, separate copy, pp. 5 and 63.—Barthelat, Laticifères de l'*Eucommia*, Journ. de bot. 1900, pp. 55-9.

[1] Perrot's statement (Tissu criblé, These, Paris, 1899, p. 144) as to the occurrence of secondary bundles of wood and bast in the primary cortex of the Schizandreae is incorrect.

[2] In retaining this Order I am guided solely by practical considerations. Recent investigations (see Solereder, loc. cit., and Hallier, in Beih. Bot. Centralbl. 1903, p. 247 et seq.) have shown that the genera *Cercidiphyllum*, *Euptelea*, and *Eucommia* must be transferred to the Hamamelidaceae, and *Tetracentron* to the Magnoliaceae. Harms' recent interpretation of the floral features of *Cercidiphyllum* (Ergänz.-Heft ii to Teilen ii-iv of the Natürl. Pflanzenfam. 1906) in no way alters my views regarding this genus.

ANONACEAE (pp. 34–39).

1. The REVIEW OF ANATOMICAL FEATURES in the first place requires amplification as regards the hairy covering. Short, simple, unicellular trichomes occur (*Polyalthia hypoleuca*, Hook. f. et Th.), but are rare. Stellate or tufted hairs have also been recorded in *Ellipeia*, and peltate hairs also in *Meiocarpidium*. Spicular cells traversing the leaf in the vertical direction are also found in *Heteropetalum brasiliense*, Benth., whilst sclerenchymatous fibres running freely in the mesophyll are also present in certain species of *Asteranthe, Heteropetalum, Sageraea*, and *Uvaria*[1]. Lastly, we may mention here the occurrence of brown middle layers in the dry leaf in species of *Popowia* and *Mezettia*.

2. STRUCTURE OF THE LEAF. The reinvestigation of the anatomy of the leaf in numerous African, American, and Asiatic species by Beyer[2] has considerably increased our knowledge of the structure of the leaf in this Order. With regard to this subject and the special types of differentiation of the **epidermis**, Beyer's treatise should be consulted. The following features presented by the integumentary tissue are of systematic importance: formation of papillae on the lower epidermis in conjunction with the development of cuticular ridges connecting the papillae with one another occurs in *Anona glauca*, Schum. et Thonn., *Cleistopholis glauca*, Pierre, *C. Staudtii*, Engl. et Diels, and *Enantia Kummeriae*, Engl. et Diels; a multiseriate (mostly two-layered) epidermis is present in certain species of *Anona, Cleistopholis, Ellipeia, Miliusa, Mitrephora, Pachypodanthium*, and *Xylopia*[3]; palisade-like elongation of the epidermal cells is also found in *Uvaria gabonensis*, Engl. et Diels; finally gelatinization of the epidermis has only been observed in *Heteropetalum brasiliense*, Benth. According to Beyer (loc. cit., p. 545), all the species which he examined appear to have stomata with subsidiary cells parallel to the pore.

According to Beyer, mechanical elements are abundant in the **veins**; vertical transcurrence of the latter by means of hard bast is also found in the genera *Anona, Ellipeia, Hexalobus, Isoloma, Miliusa, Mitrephora, Polyceratocarpus, Sageraea, Uvaria* and *Xylopia*.

Beyer found that the **secretory cells** were present throughout. *Stenanthera gabonensis*, Engl. et Diels is especially characterized by having two superposed layers of secretory cells in the spongy tissue. In *Xylopia tenuifolia* the walls of the secretory cells exhibit stratification. The branched spicular cells and the spicular fibres found in the mesophyll have already been mentioned above (see under 1).

Beyer reinvestigated the crystals of **oxalate of lime**, which afford important characters for systematic purposes. According to him also the occurrence of solitary and clustered crystals of oxalate of lime in the epidermis of the leaf is an important ordinal character. In other respects Beyer did not find in all cases that the older statements of Borodin were quite correct; it will therefore be best to reproduce in the following paragraphs Beyer's review of

[1] The species in which Beyer has recently met with spicular fibres are as follows: *Anona glauca*, Schum. et Thonn., *A. senegalensis*, Pers.; *Asteranthe Asterias*, Engl. et Diels; *Guatteria australis*, St. Hil., *G. Sellowiana*, Schlecht., *G. villosissima*, St. Hil.; *Heteropetalum brasiliense*, Benth.; *Sageraea elliptica*, Hook. f. et Th.; *Uvaria Afzelii*, *U. angolensis*, Welw., *U. caffra*, E. Mey., *U. ceylanica*, L., *U. Dinklagei*, Engl. et Diels, *U. Kirkii*, Oliv.

[2] Beyer's investigations extend to numerous species belonging to forty genera.

[3] These are: *Anona glauca*, *A. Klainei*, Pierre, *A. palustris*, L., *A. senegalensis*, Pers., *A. squamosa*, L.; *Cleistopholis albida*, Engl. et Diels (with a typical two-layered epidermis according to Beyer's figure); *Ellipeia leptopoda*, King; *Miliusa indica*, Lesch.; *Mitrephora Maingayi*, King; *Pachypodanthium confine*, Engl. et Diels; *Xylopia aethiopica*, A. Rich., *X. africana*, Oliv.

the nature and mode of occurrence of the crystals in the upper epidermis of the leaf:

(*a*) All the cells of the epidermis, or only isolated cells containing each a single clustered crystal:—*Anaxagorea, Anona, Anonidium, Artabotrys, Asteranthe, Cleistopholis, Duguetia, Eupomatia, Goniothalamus, Heteropetalum, Hexalobus, Meiocarpidium, Monodora, Pachypodanthium, Polyalthia, Popowia, Rollinia, Unona, Uvaria, Xylopia.* (Exceptions: *Monodora Preussii*, Engl. et Diels—clustered and solitary crystals; *Popowia elegans*, Engl. et Diels—clustered crystals in upper, solitary crystals in lower epidermis; *Xylopia africana*, Oliv.—occasional solitary crystals in both upper and lower epidermis.)

(*aa*) Clustered and solitary crystals:—*Bocagea* (with round crystal-cells), *Ellipeia, Guatteria.*

(*b*) Cells of the epidermis (usually all of them) containing each a solitary crystal:—*Enantia, Melodorum, Miliusa, Sageraea* (not all the cells in this case), *Uvariopsis.*

(*bb*) Solitary crystals chiefly present in the epidermal cells of the veins, also in scattered cells in the rest of the epidermis:—*Alphonsea, Ephedranthus, Mitrephora.*

(*c*) Crystals not observed:—*Cananga, Isoloma, Mezettia, Oxymitra, Polyceratocarpus, Stenanthera.*

In investigating the **hairy covering** Beyer met with trichomes of a type new to the Order, viz. the unicellular clothing hairs mentioned above (see section 1). According to the same authority uniseriate clothing hairs are widely distributed in the Order (*Anona, Asteranthe, Cananga, Enantia, Ephedranthus, Goniothalamus, Guatteria, Heteropetalum, Hexalobus, Melodorum, Miliusa, Oxymitra, Piptostigma, Popowia, Rollinia, Unona, Uvaria* (*Asimina* and Sect. *Uvariodendron*), *Xylopia*). They consist of two or three cells, of which the terminal cell is invariably longer than the others, and sometimes (*Anona, Rollinia*) of remarkable length. Stellate or tufted hairs also occur in species of *Ellipeia*, whilst peltate hairs[1] are also found in *Meiocarpidium lepidotum*, Engl. et Diels. The rays of the tufted hairs in *Uvaria lurida*, Hook. f. et Th. (sphalm. '*lucida*' in Beyer's paper) are multicellular and uniseriate owing to the presence of one or more division-walls, a point which I am able to confirm.

3. Structure of the Axis. According to recent investigations stone-cells are very commonly present in the **pith**; they are but rarely absent (*Asimina* and *Monodora* besides *Eupomatia*). Well-developed diaphragms composed of stone-cells are also found, for example, in species of *Goniothalamus, Guatteria, Hexalobus, Melodorum, Popowia*, and *Stenanthera.*

With regard to the structure of the **wood** and **cortex**, Beyer confirms the anatomical characters which I pointed out as important in the diagnosis of the Order, for the material which he investigated. Stone-cells are of occasional occurrence in the bast, but never show such a regular arrangement as in the cortex of *Guatteria villosissima*, St. Hil., described by Möller. Beyer demonstrated superficial development of the cork also in *Cleistopholis* and *Uvariopsis.*

We may add that the species of *Melodorum* examined by Beyer agree with the species described by Schenck in having normal structure in the stem.

Literature: Börgesen og Paulsen, Veget. dansk-vestind. Öer, Bot. Tidsskrift, xxii, 1898–9, pp. 50, 51 (*Anona palustris*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 104.—Areschoug, Mangrovepfl., Bibl. bot., Heft 56, 1902, p. 63 and Tab. vii.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 295 (*Xylopia*).—H. Beyer, Anatomie der Anonaceae, insbes. d. afrikan., in Engler, Bot.

[1] Beyer doubts the correctness of O. Bachmann's statement as to the occurrence of peltate hairs in *Anona furfuracea*, St. Hil., or the correct determination of the plant examined by Bachmann; but in this he is wrong. In Martius, Fl. brasil., xiii, 1, p. 8, we find the following statement with reference to this species: 'folia . . . superne parcius lepidota, pilis stellatis.' Whether the species belongs to the genus *Anona* is a different question.

Jahrb., xxxi, 1902, pp. 516–55; see also Engler, Monogr. afrikan. Pflanzenfam.: vi. Anonaceae, 1901.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl. 39, n. 2, 1905, pp. 126–30 (*Anona*, *Artabotrys*), pp. 142–4 and Tab. xxi xxii (*Goniothalamus*), and pp. 156–8 (*Cyathocalyx*).—[For additional literature see p. 1169.]

MENISPERMACEAE (pp. 39–43).

1. In the Review of the Anatomical Features the following corrections or additions are necessary. A uniform and characteristic type of stoma is not present. In the axis the pericycle sometimes (*Cissampelos fasciculata*, Benth.) contains no sclerenchymatous elements. Secretory sacs of varying length, besides occurring in *Anamirta*, &c., have been recorded in the genera *Albertisia*, *Antizoma*, *Calycocarpum* (?), *Chasmanthera*, *Cocculus*, *Desmonema*, *Disciphania*, *Fawcettia*, *Fibraurea*, *Hypsipodes*, *Kolobopetalum*, *Parabaena*, *Pericampylus* (?), *Syntriandrium*, *Tiliacora*, *Tinomiscium* and *Triclisia*, whilst open intercellular secretory spaces have been shown to be present in certain species of *Anomospermum*, *Miersiophyton* and *Tinospora*. Anomalous structure of the axis (viz. the occurrence of secondary vascular bundles in various regions) has recently been stated to occur also in species of *Chasmanthera*, *Menispermum*, and *Stephania*. Oxalate of lime is deposited in the following special forms: large ordinary, solitary crystals in the veins of the leaf in *Burasaia*, *Chasmanthera*, *Chlaenandra*, *Fawcettia*, *Hypsipodes*, *Kolobopetalum*, *Leichhardtia*, *Syntriandrium*, *Tinospora*; rather large crystals resembling styloids and situated in the leaf in pairs of epidermal cells and in the palisade-tissue in *Leichhardtia clamboides*, F. v. Müll.; large clustered crystals in species of *Chondrodendron* and *Syrrhonema*, smaller crystals of this type in species of *Macrococculus* and *Pericampylus*. The trichomes of the Menispermaceae are either typical clothing hairs or hairs of a glandular nature. No member of the Order has been found to have exclusively unicellular clothing hairs. The typical clothing hairs for the most part consist of two cells, a short basal cell and a long terminal cell. Uniseriate clothing hairs composed of more than two cells have been observed only in species of *Anamirta*, *Arcangelisia*, *Calycocarpum*, *Chasmanthera*, *Coscinium*, *Disciphania*, *Heptacyclum*, *Menispermum* (together with two-celled hairs), *Parabaena*, *Stephania*, *Tinospora* (here accompanied by unicellular hairs). Besides the glandular shaggy hairs of *Jateorhiza* we may mention the following types of glandular hairs: the small unicellular, ellipsoidal or club-shaped trichomes present in species of *Kolobopetalum*, *Miersiophyton* and *Tinospora*; and the longer uniseriate trichomes found in species of *Calycocarpum* and *Parabaena*. The unicellular hydathodes, first recorded by Haberlandt in *Anamirta*, are also found in *Arcangelisia*. Peculiar small rosettes of silicified cells occur in the epidermis of the leaf in *Coscinium Blumeanum*, Miers. We may add the following special features presented by the leaf in certain species to the enumeration given in the earlier portion of this work: the papillose or sclerotic differentiation of epidermal cells: the very rare occurrence of a hypoderm or of a locally two-layered epidermis; the very rare arrangement of the stomata in groups; the occurrence in the mesophyll of arm-palisade tissue (scarcely typically differentiated), and of spicular cells differentiated as hairs or assuming some other form; the presence of tubular cells filled with siliceous substance at the ends of the veins, &c.

2. Structure of the Leaf[1]. Recent investigations have shown that

[1] Recent researches on the structure of the leaf, the results of which lie before me in manuscript, have been carried out under my guidance by K. Krafft, who continued Auer's uncompleted investigations (see the earlier part of this work, p. 40, footnote). Krafft's researches extend to the following genera, which are enumerated according to Engler and Prantl's system: I. Cocculeae: *Menispermum*, *Pericampylus*, *Sarcopetalum*, *Cocculus*, *Diploclisia*, *Stephania*, *Antizoma*, *Cissampelos*, *Peraphora*, *Cyclea*, *Tiliacora*, *Abuta*; II. Tinosporeae: *Husemannia*, *Jateorhiza*, *Tinospora*,

bifacial structure of the leaf is far more widely distributed than centric. The palisade and spongy tissue show a very varied type of differentiation. Krafft records the presence of marginal pits in the **epidermis** in species of *Abuta*, *Adeliopsis*, *Anomospermum*, *Arcangelisia*, *Bania*, *Cocculus*, *Fawcettia*, *Heptacyclum*, *Husemannia*, *Hyperbaena*, *Limacia*, *Macrococculus*, *Pachygone* and *Pycnarrhena*, where he found them in nearly all cases on both sides of the leaf, while in *Adeliopsis* they are confined to the upper epidermis. In the course of the recent investigations gelatinization of isolated epidermal cells has not been observed in any species. But subepidermal layers of mucilage similar to those described by Auer in *Anomospermum reticulatum* are rather widely distributed; each patch of mucilage is derived from the inner walls of a group of upper epidermal cells and the adjacent walls of the uppermost layer of palisade-cells; this feature is found in *Adeliopsis*, *Anomospermum* pro parte, *Cissampelos* pro parte, *Cyclea* pro parte, *Limacia* pro parte, and *Stephania* pro parte. Epidermal cells of exceptional size are stated by Krafft to occur in *Antizoma* and *Cocculus* pro parte, especially on the upper side of the leaf; the same author mentions the presence of sclerotic epidermal cells situated over the veins on both sides of the leaf in *Anomospermum reticulatum*, Eichl., *Hyperbaena laurifolia*, Urb. and *Triclisia loucoubensis*, Baill. Papillose differentiation of the epidermis in the leaf has also been observed: (*a*) on both sides in *Antizoma calcarifera*, Miers, *A. lycioides*, Miers, *Cissampelos capensis*, Thunb., *C. Pareira*, L. (not in all the forms of this polymorphic species), *Cocculus Leaeba*, DC. and *Stephania rotunda*, Lour. (not all the cells papillose in this case); (*b*) on the lower side only in *Cissampelos fluminensis*, Eichl. (slightly papillose), *C. glaberrima*, St. Hil., *C. Pareira* pro parte (see above), *Diploclisia macrocarpa*, Miers, *Hypsipodes subcordatus*, Miq., *Jateorhiza Columba*, Miers, *Menispermum dauricum*, DC. (isolated cells above the veins), *Miersiophyton kamerunense*, Engl. (isolated cells above the veins), *Peraphora robusta*, Miers, *Stephania abyssinica*, Walp., *S. discolor*, Spreng., *S. elegans*, Hook. f. et Th., *S. hernandifolia*, Walp. and *S. rotunda*, Lour. Curiously enough there is no new record of a species with hypoderm; in *Parabaena sagittata*, Miers, the upper epidermis consists locally of two layers. A special type of differentiation is exhibited by the upper epidermis in *Desmonema pallide-aurantiaca*, Engl. et Gilg, both the outer and inner walls being very strongly thickened and partly converted into mucilage, and by the upper epidermis in *Chlaenandra ovata*, Miq., in which the strongly thickened outer walls project convexly into the lumina of the cells. Finally, a distinctly peculiar feature of the epidermis is presented by the small groups of silicified cells in *Coscinium Blumeanum*, Miers. They are situated in the upper epidermis and lie immediately above the sclerenchyma of the smaller vertically transcurrent veins. They consist of a small central cell, which is rounded in surface-view and might possibly be interpreted as the rudiment of a hair, and of a rosette of cells with unevenly thickened walls, which in surface-view have the same appearance as the well-known cystolith-like bodies in the subsidiary cells of the trichomes of *Lithospermum* and other Boragineae. In some cases two of these groups of silicified cells are united. Regarding their function nothing is known.

In very many Menispermaceae the **stomata** are surrounded by ordinary neighbouring cells. A definite and uniform type of stoma is not present. Not

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Fawcettia, *Miersiophyton*, *Chasmanthera*, *Hypsipodes*, *Desmonema*, *Parabaena*, *Disciphania*, *Kolobopetalum*, *Syntriandrium*, *Calycocarpum*, *Anamirta*, *Coscinium*, *Arcangelisia*, *Chlaenandra*; III. Limacieae: *Anomospermum*, *Limacia*; IV. Pachygoneae: *Triclisia*, *Heptacyclum*, *Pycnarrhena*, *Macrococculus*, *Pleogyne*, *Sciadotaenia*, *Albertisia*, *Pachygone*, *Hyperbaena*, *Chondrodendron*, *Detandra*, *Carronia*, *Adeliopsis*, *Bania*, *Syrrhonema*, *Leichhardtia*. Additional recent statements on the structure of the leaf and axis are further also to be found in Maheu's papers, ll. cc.

uncommonly, however, one observes a tendency for subsidiary cells to develop in connexion with all or some of the stomata; according to Krafft this is the case in: *Albertisia* (subsidiary cells arranged like a rosette), *Anamirta, Bania* (rosette-like subsidiary cells), *Burasaia* pro parte (4–6 neighbouring cells, of which one is placed parallel to the pore on either side), *Carronia* (rosette-like subsidiary cells), *Chlaenandra* (neighbouring cells with thin walls, so that they appear as subsidiary cells), *Cocculus, Cyclea* pro parte, *Fawcettia, Heptacyclum, Husemannia* (rosette-like subsidiary cells), *Hyperbaena* (subsidiary cells rosette-like in *H. laurifolia*, Urb.), *Leichhardtia* (4–6 neighbouring cells, one being placed on either side of and parallel to the pore), *Limacia* pro parte, *Macrococculus* (subsidiary cells rosette-like), *Parabaena, Pleogyne, Pycnarrhena* (narrow subsidiary cells), *Sarcopetalum*. In *Macrococculus pomiferus*, Becc. several pairs of guard-cells with their subsidiary cells together form stomatal groups, separated from one another by rows of ordinary epidermal cells, without stomata and differently shaped. The only additional record of the occurrence of stomata on the upper side of the leaf is in *Antizoma* pro parte.

The previous statements regarding the structure of the **mesophyll** require the following additions. The thickenings and swellings confined to certain portions of the wall in cells of the palisade and spongy tissues, first recorded by Auer in *Stephania hernandifolia*, are stated by Krafft to occur in *Adeliopsis, Carronia, Cissampelos, Cocculus* pro parte, *Cyclea, Limacia* pro parte, *Pachygone, Pericampylus, Stephania* and *Syrrhonema*. The palisade-tissue in *Disciphania lobata*, Eichl. is composed of a single layer of short cells, and shows slight differentiation as arm-palisade-tissue. In certain species a part or the whole of the spongy tissue has thick walls, which are then in most cases lignified; this feature is found in *Albertisia papuana*, Becc., *Anamirta Cocculus*, Wight et Arn., *Bania thyrsiflora*, Becc., *Husemannia protensa*, F. v. Müll. and *Parabaena sagittata*, Miers. Mechanical elements are also frequently developed in the mesophyll. The following types are found: isolated palisade-cells resembling idioblasts, and strongly thickened, but with wide lumina, in *Coscinium Blumeanum*, Miers; isolated sclerosed cells belonging to the spongy tissue or entire layers of such cells near the lower epidermis in *Abuta concolor*, Poepp. et Endl.; branched stone-cells in the neighbourhood of the vascular bundles of the larger veins in *Chlaenandra ovata*, Miq.; slightly or considerably developed branches of the sclerenchyma of the veins, though not typically fibrous, in the mesophyll in *Abuta concolor*, Poepp. et Endl., *Chondrodendron platyphyllum* (Miers), and *Detandra paraënsis* (Eichl.); spicular fibres, which branch off from the sclerenchyma of the veins into the mesophyll, in *Anamirta Cocculus*, Wight et Arn. and *Arcangelisia lemniscata*, Becc.; girder-shaped spicular cells, which traverse the entire thickness of the leaf-tissue from one epidermis to the other, in *Heptacyclum Zenkeri*, Engl. (where they have wide lumina, and are sac-like, often dichotomously divided, and give off root-like branches beneath the epidermis), *Anamirta Cocculus* (like fibres and unbranched), *Burasaia gracilis*, Decne., *B. congesta*, Decne. (branched with transitions to hair-like differentiation), and probably also in *Tinomiscium reticulatum*, Miers ('piliers' according to Maheu); girder-like spicular cells, which essentially belong to the palisade-tissue only, branch beneath the upper epidermis, and give off rays into the spongy tissue, while they show transitions to hair-like differentiation, in *Adeliopsis decumbens*, Benth. (subepidermal rays penetrating the subepidermal layer of mucilage), *Burasaia madagascariensis*, DC., and *Limacia cuspidata*, Hook. f. et Th. (Cuming, No. 1252, Philippines, subepidermal rays penetrating the subepidermal layer of mucilage); lastly, spicular cells differentiated like hairs in the spongy tissue in *Adeliopsis decumbens* (star-shaped), *Anomospermum japurense*, Eichl. (with few rays), *Limacia cuspidata* and *L. microphylla*, Miq. (star-shaped).

The vascular bundles of the **veins** are in most cases accompanied by well-developed sclerenchymatous tissue. According to Krafft, exceptions to this rule are found, especially in *Antizoma*, *Cissampelos* pro parte, *Desmonema*, *Diploclisia*, *Disciphania*, *Miersiophyton*, *Stephania* pro parte and *Tinospora* pro parte; in these the sclerenchyma is absent. In very many genera and species the lateral veins of the second order, and even some of the next smaller size, tend to be vertically transcurrent by means of special parenchymatous or sclerenchymatous tissue accompanying them. According to Krafft, the following genera and species may be especially mentioned as examples of this: *Diploclisia* and *Menispermum* (veins vertically transcurrent by means of tissue, which is not sclerosed), *Heptacyclum*, *Hyperbaena*, *Limacia microphylla*, Miq., *Macrococculus*, *Peraphora*, *Pericampylus*, *Pycnarrhena*, *Sarcopetalum* and *Triclisia* (veins vertically transcurrent by means of a sclerenchymatous ring), *Abuta*, *Anomospermum reticulatum*, Eichl., *Coscinium*, *Limacia velutina*, Miers and *Pachygone* (veins vertically transcurrent by means of regular plates of sclerenchyma). The structure of the smaller veins of *Chondrodendron platyphyllum*, Miers is also noteworthy; these veins, which project on the lower side, are vertically transcurrent on the upper by means of sclerenchymatous plates, whilst on the lower side a group of palisade-cells forming a single layer adjoins the vascular bundle.

The forms in which **oxalate of lime** is deposited are very numerous, as may be gathered from the previous description. Specially common types are the crystals, varying in size, of prismatic, acicular, rhombohedral or other shapes, with transitions to styloid-like crystals or crystal-sand; other common forms are small or sometimes larger clustered crystals, and ordinary large solitary crystals. In most cases oxalate of lime is excreted in abundance, being present not only in the mesophyll and veins, but often also in the epidermis. The only cases in which Krafft found no oxalate of lime in the leaf were *Abuta Grisebachii*, Tr. et Pl., *A. Imene*, Eichl., *Miersiophyton kamerunense*, Engl. and *Sciadotaenia amazonica*, Eichl. Only the typical and principal forms of crystals can be employed for systematic purposes, since the others are frequently connected by transitional forms, so that their delimitation becomes difficult. In the first place the occurrence of the following types may be mentioned as specially important; ordinary large solitary crystals are found in the veins in *Burasaia* pro parte, *Chasmanthera*, *Chlaenandra*, *Fawcettia*, *Hypsipodes*, *Kolobopetalum*, *Leichhardtia*, *Syntriandrium* and *Tinospora*; somewhat smaller rhombohedral crystals are present in *Abuta* pro parte, *Anomospermum*, *Burasaia* pro parte, *Heptacyclum*, *Husemannia*, *Hyperbaena* pro parte, *Limacia*, *Macrococculus*, *Pachygone*, *Pleogyne*, *Pycnarrhena* and *Tiliacora* pro parte; rather large, styloid-shaped or prismatic crystals, which under a low magnification give the appearance of the veins being striulated, occur in *Cissampelos* pro parte, *Cyclea* pro parte, *Diploclisia macrocarpa*, Miers, *Jateorhiza Columba*, Miers, *Pericampylus incanus*, Miers and *Stephania*; rather large styloid-like, mostly geniculate, hemitropic crystals are found in numerous cells of the palisade-tissue in *Leichhardtia clamboides*, F. v. Müll.; large clustered crystals are present in the palisade-tissue in the immediate neighbourhood of the vascular bundles of the veins in *Chondrodendron platyphyllum*, Miers and *Syrrhonema fasciculatum*, Miers, smaller clustered crystals in the palisade-tissue of the veins in *Pericampylus incanus*, and small clustered crystals or aggregates resembling clustered crystals singly in the palisade-cells of *Macrococculus pomiferus*. The epidermis, as mentioned above, frequently contains various forms of oxalate of lime. In *Desmonema pallide-aurantiaca*, Engl. et Gilg and *Tiliacora Warneckei*, Engl., in particular, and also in *Anamirta Cocculus* the epidermis on both sides is differentiated as a regular crystal-containing armour; the cells in this case contain chiefly large rhombohedral crystals. Finally, we

may mention the paired crystal-cells, found in the upper epidermis of *Leichhardtia clamboides*; these, like the paired crystal-cells of *Canavalia villosa* (see Systematic Anatomy, p. 265, Fig. 58, *C*), as a rule contain hemitropic crystals resembling styloids. Krafft met with sphaerocrystalline masses composed of an unknown chemical substance in the lower epidermis of *Sarcopetalum Harveyanum*, F. v. Müll. In *Arcangelisia lemniscata* tubular cells filled with a siliceous substance are found at the ends of the smaller veins.

Several additions may be made to the earlier statements on the **secretory receptacles** of the Menispermaceae, which referred for the most part to those occurring in the axis. In the first place we may note that, besides secretory cells of varying length and with diverse contents, there are also open intercellular secretory receptacles. The latter are situated singly in the meshes of the veins, and are often enclosed by arc-shaped cells of the spongy tissue; Krafft met with them in the genus *Tinospora* (but only in *T. Bakis*, Miers), and also in *Anomospermum japurense*, Eichl. and *Miersiophyton kamerunense*, Engl. The nature of the secretion varies. As regards the distribution of the secretory cells, we may in the first place enumerate those genera in which Krafft met with no secretory cells in the leaf, or only found them in a certain number of species; these are: *Abuta, Adeliopsis, Anomospermum, Arcangelisia, Bania, Calycocarpum, Carronia, Chlaenandra, Chondrodendron, Cocculus* pro parte, *Coscinium, Cyclea, Detandra, Heptacyclum, Husemannia, Hyperbaena, Leichhardtia, Limacia* pro parte, *Macrococculus, Menispermum, Miersiophyton, Pachygone, Peraphora, Pericampylus, Pleogyne, Pycnarrhena, Sarcopetalum, Sciadotaenia, Stephania* and *Syrrhonema*. The secretory cells in the leaf are frequently restricted to the veins, being for the most part associated with the sclerenchyma of the latter, and sometimes even embedded in it; they then usually have an elongated shape, like the secretory cells of the axis. It is not so common to find the secretory cells free in the mesophyll, where they occur in the form of rather short sacs; when this is the case the veins also generally contain short secretory sacs only, more rarely sacs of greater length. The contents of the secretory sacs vary greatly. In herbarium-material the long sacs in the veins mostly have yellowish contents, which after treatment with eau de Javelle resemble latex; sometimes, however, they are brown. In the short sacs the secretion generally has a reddish-brown colour, but in some cases it resembles gum, e.g. in *Antizoma*. Hallier informs me that *Fibraurea* possesses white latex. Maheu has recently discovered contents resembling caoutchouc, and capable of being drawn out into threads when parts of the branches or leaves are broken across, in the secretory sacs of *Tinomiscium javanicum*, Miers, *T. petiolare*, Miers, and *T. phytocrenoides*, Kurz; these sacs are 120–150 μ long, and occur in the stem at the margin of the pith, and on the outer side of the arcs of pericyclic hard bast, and in the leaf especially in the neighbourhood of the veins. Poulsen met with mucilaginous contents in the aerial roots of *Tinospora crispa*, Miers.

Elongated secretory sacs with yellowish or brownish contents have been shown by Krafft to occur in the veins of the leaf in the following genera: *Albertisia, Anamirta, Burasaia, Chasmanthera, Cissampelos* pro parte, *Cocculus* pro parte (in most cases), *Desmonema, Disciphania, Fawcettia, Hypsipodes, Jateorhiza, Kolobopetalum, Limacia* pro parte, *Parabaena, Syntriandrium, Tiliacora, Tinospora*; short secretory sacs, which mostly have reddish-brown contents, and are sometimes recognizable in transmitted light by using a lens, were found to occur independently in the mesophyll, and, where expressly stated, also in the veins in: *Antizoma calcarifera*, Miers, *A. lycioides*, Miers (also in the veins), *Cissampelos Pareira* pro parte, *C. fasciculata*, Benth., *Diploclisia macrocarpa*, Miers (also in the veins), *Tiliacora racemosa*, Colebr., *Triclisia louconbensis*, Baill. (also in the veins, and in the mesophyll sometimes in rows).

The earlier statements and those of Krafft agree with regard to the occurrence

of elongated secretory sacs in the petiole and axis in species of *Anamirta, Burasaia, Cissampelos, Diploclisia, Jateorhiza, Limacia* and *Tinospora*. Maheu has recently demonstrated secretory sacs also in *Fibraurea chloroleuca* (= *F. tinctoria*, Lour. ex syn.), *Calycocarpum* sp., and *Pericampylus* sp., as well as in additional species of *Burasaia, Cissampelos*, and *Cocculus*; in view of Krafft's results Maheu's statements with reference to *Calycocarpum* and *Pericampylus* require re-examination and confirmation.

Owing to recent investigations our knowledge of the **hairy covering** of the Menispermaceae is much more complete than formerly. The trichomes may be classified under typical clothing hairs and glandular hairs, but the precise function of the latter remains to be determined in living material. A specially noteworthy feature of the typical clothing hairs is that they are not exclusively unicellular in any member of the Order. Krafft, moreover, only records these unicellular hairs in *Tinospora Bakis*, where they represent a reduced form of the multicellular clothing hairs. Blottière's earlier statement regarding the presence of unicellular clothing hairs in *Abuta rufescens* is incorrect and may be disregarded. The most widely distributed form of clothing hair is represented by bicellular trichomes with a short basal cell and a longer terminal cell of varying length. Points of difference are found in the structure of the basal cell, the upper end of which frequently passes over into a stalk-like process of varying length and either solid or provided with a lumen, as well as in the nature of the wall and lumen of the terminal cell. These bicellular clothing hairs have been recorded in the following genera: *Abuta, Adeliopsis, Albertisia, Antizoma, Bania, Carronia, Chondrodendron* (with a specially long terminal cell), *Cissampelos, Cocculus, Cyclea, Detandra* (with a specially long terminal cell), *Husemannia, Hyperbaena, Limacia, Macrococculus, Menispermum* (accompanied by three-celled hairs, see below), *Pachygone, Peraphora, Pericampylus, Pleogyne, Pycnarrhena, Sciadotaenia,-Syrrhonema, Tiliacora*. The two following forms of hairs may be interpreted as modifications of the bicellular trichomes: (*a*) those of *Anomospermum reticulatum*, Eichl., in which the basal cell undergoes subsequent division by thin vertical walls; and (*b*) the three-celled trichomes accompanying others composed of two cells in the species of *Menispermum*; here a third cell is intercalated between the basal and terminal cell, and is delimited from the latter by an oblique wall. The trichomes of *Menispermum* constitute a transition to the uniseriate clothing hairs, which are composed of more than two cells, and exhibit various types of differentiation. The uniseriate hairs are found in the following species: *Anamirta Cocculus* (3–6-celled, with thick division-walls; especially on the domatia), *Arcangelisia lemniscata*, Becc. (3–8-celled, with both thick and thin division-walls; only on the domatia), *Calycocarpum Lyonii*, Nutt. (very long, composed of 4–7 cells, and with thin division-walls), *Chasmanthera dependens*, Hochst. and *C. strigosa*, Baill. (2–6-celled, those of *C. strigosa* with subsidiary cells, each of which contains a large solitary crystal of oxalate of lime), *Disciphania lobata*, Eichl. (3–7-celled), *Heptacyclum Zenkeri*, Engl. (3–7-celled, recurved at the base), *Parabaena sagittata*, Miers (2–5-celled, with thick division-walls; see under the forms of glandular hairs), *Stephania discolor*, Spreng. and *S. hernandifolia*, Walp. (5–10-celled, with thin walls, a number of cells being sometimes placed side by side at the base of the hair), *Tinospora Bakis*, Miers (2–4-celled, conical, occasionally biseriate at the base). Lastly, to this type of hair we may also refer the characteristic 5–8-celled, uniseriate clothing hairs of *Coscinium Blumeanum*, Miers, these being composed of several short basal cells exhibiting uniseriate arrangement, and a very long flagelliform terminal cell; in a certain sense these again form a transition to bicellular clothing hairs with a short basal cell.

Amongst the glandular forms of hairs we may firstly include the small unicellular club-shaped or ellipsoidal trichomes (possibly hydathodes), which

either occur singly on the leaf-surface, especially in the neighbourhood of the veins (and sometimes sunk singly in small pits, e.g. in *Tinospora auriculata*, Engl.), or lie in groups at the base of the lamina in the angles formed by the principal veins on the lower side of the leaf, heing sometimes situated in small pit-like depressions (domatia ?). These unicellular club-shaped trichomes have only been recorded in the following species: *Kolobopetalum auriculatum*, Engl., *Miersiophyton kamerunense*, Engl., *Tinospora auriculata*, Engl., *T. Bakis*, Miers, *T. cordifolia*, Miers and *T. reticulata*, Miers. With these unicellular club-shaped trichomes we may class the glandular shaggy hairs of *Jateorhiza Columba*, represented in Fig. 7, *A* in this work. Finally, we may mention here the uniseriate trichomes of *Calycocarpum Lyonii* (narrowed basally, and thin-walled throughout), and *Parabaena sagittata* (3-celled, club-shaped, with a specially thin-walled terminal cell), which are apparently glandular and may be derived from the typical clothing hairs found in these species.

Krafft met with unicellular hydathodes, having the same structure as those of *Anamirta Cocculus* (according to Haberlandt), in the upper and lower epidermis of the veins in the leaf of *Arcangelisia lemniscata*. He made the interesting ohservation that in both species the walls of the hydathodes, originally composed of cellulose, became subsequently suberized, and that additional thickening layers, which are lignified and also pitted, are deposited on the suberized wall, naturally involving the loss of function of the hydathodes.

Typical domatia in the form of small pits are found in the angles formed by the veins of the second order in *Anamirta Cocculus* and *Arcangelisia lemniscata*. The entrance to the pits is clothed with hairs.

3. Structure of the Axis. According to Maheu, the development of **cork** takes place in various positions: either in the epidermis (*Tinomiscium petiolare*), or in the subepidermal layer (*Menispermum*), or first in the primary cortex and then in the pericycle ('*Cissampelos obovata*, DC.'). In *Menispermum canadense* and species of *Abuta*, *Cocculus* and *Pericampylus* Damm observed the formation of 'a cuticular epithelium,' which sooner or later becomes replaced by cork.

The following additional forms are stated by Maheu to exhibit an **anomalous structure** in the axis: *Chasmanthera*, *Cissampelos hexandra* (= *Stephania discolor*, Spr. ex syn.), *Cocculus Thunbergii* and *Menispermum*. According to Maheu, the origin of the anomalous growth is not always the same.

In the first case (in an unnamed species of *Menispermum*) the secondary vascular bundles originate, according to Maheu, in the primary cortex; in the second case, which is the most widely distributed (*Pareira brava* = *Chondrodendron tomentosum*, Ruiz et Pav. ex syn. and *Cocculus laurifolius*, DC.; see also Gérard with reference to *Abuta rufescens* and *Chondrodendron platyphyllum*) they arise in a secondary tissue, formed by division of the endodermis; in the third case (*Cocculus Leaeba*, DC. and *Cissampelos Pareira*) they appear in the pericycle; and in the fourth and last case (*Abuta Selloana*, *Anomospermum grandifolium*, *Cocculus platyphyllus* = *Chondrodendron platyphyllum*, ex syn., *Cissampelos Mauritiana*, Wall. = *Pericampylus incanus*, Miers ex syn.) immediately external to the soft bast of the normal ring of bundles. With reference to *Cocculus Thunbergii* and *Cissampelos hexandra* I quote Maheu's own words: 'le cambium peut être inactif, par places ou progressivement sur toute sa surface; il apparaît alors en dehors de lui une nouvelle assise génératrice.'

Literature: Gérard, Form. anom. des Ménisperm., Comptes rendus, Paris, ciii, 1886, pp. 1027, 1028.—[Heckel et Schlagdenhauffen, Bakis et Sangol, Ann. Inst. col. Marseille, iii, 1895, p. 49 et seq.]—Schwabach, in Bot. Centralbl. 1898, iv, p. 359.—Spanjer, Wasserapparate, Bot. Zeit. 1898, i, p. 61.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 50–53.—Damm, Mehrjähr. Epid., Beih. Bot. Centralbl., xi, 1902, especially pp. 236–9.—Maheu, Rech. anat. sur les Ménisperm., Journ. de bot. 1902, pp. 369–78; see also Congrès internat. de Pharm., sep. copy, 7 pp. (received xii, 1904).—Poulsen, Luftrødderne hos *Tinospora crispa*, Vidensk. Meddelels. Kjøbenhavn, 1902, pp. 235–7.—

Morini, Stud. anat. del caule delle Menisperm., Mem. Accad. Bologna, 1904.—Areschoug, Trop. värt. bladbyggn., Sv. Vet. Akad. Handl. 39, n. 2, 1905, pp. 21, 22 and Tab. xxiv (*Pericampylus*).—Maheu, Laticifères à caoutchouc : *Tinomiscium*, Comptes rendus, Paris, 4 déc. 1905, sep. copy, 2 pp. —[For additional literature, see p. 1171.]

BERBERIDEAE (pp. 44-47).

1. In the REVIEW OF THE ANATOMICAL FEATURES the following changes and additions are necessary. Glandular hairs with a uniseriate stalk and an ellipsoidal multicellular head occur in *Epimedium*. Differentiation of papillae on the epidermal cells of the leaf (occasionally on those of the upper side as well) is also found in numerous species of *Berberis* and in certain species of *Epimedium* and *Berberidopsis*. In certain species of *Berberis* and *Mahonia* a parenchymatous hypoderm is situated beneath the upper epidermis of the leaf, and in very many species of these two genera there is a hypoderm, composed of sclerenchymatous fibres, in the same position. The tendency of the vascular bundles in the subaerial stem to show an arrangement, like that typical of Monocotyledons, is at least indicated in other herbaceous members of the Order besides those previously mentioned. The nature of the pericycle varies. The cork either arises on the inner side of the groups of pericyclic fibres, or in the primary cortex, sometimes in a subepidermal position.

2. STRUCTURE OF THE LEAF. The structure of the leaf in the genera belonging to the tribe Berbereae is now well known, owing to the investigations of Citerne, Köhne, Fedde and C. K. Schneider. The **epidermis** furnishes numerous anatomical characters suitable for specific diagnosis, e.g. besides the shape of the cells, firstly the nature of the cell-wall, and the frequent occurrence of papillae[1] in *Berberis* and *Mahonia*. Cuticular beads are also found

[1] According to Citerne and others, the formation of papillae on the lower side of the leaf has been demonstrated in the following species: *Berberis agapatensis*, *B. armata*, *B. asiatica*, *B. brachybotrya*, *B. carinata*, *B. chilensis*, *B. concinna*, *B. corymbosa*, *B. dasystachya*, *B. densiflora*, Köhne, *B. diaphana*, *B. dictyophylla*, *B. diffusa*, *B. empetrifolia*, *B. ferox*, *B. ferruginea*, *B. flexuosa*, *B. Gayi*, *B. glauca*, *B. Goudotii*, *B. Grisebachii*, *B. guilache*, *B. heteropoda* var. *papillosa*, *B. horrida*, *B. laurina*, *B. lycium*, *B. macrosepala*, *B. ovata*, *B. pallens*, *B. papillifera*, Köhne, *B. pichenensis*, *B. pyrocarpa*, Köhne, *B. repens*, Lindl., *B. rigidifolia*, *B. saxicola*, *B. serratodentata*, *B. sinensis*, *B. tolimensis*, *B. Tohonoskiana*, *B. umbellata*, Wall., *B. virescens*, Hook. f., *B. Weddellii*, *B. yunnanensis*; *Mahonia angustifolia* (Hartw.), *M. Fremontii* (Torr.), *M. haematocarpa* (Woot.), *M. incerta*, Fedde, *M. pinnata* (Lag.), *M. pumila* (Greene), *M. repens*, Don, *M. trifoliolata* (Moric.); *Epimedium Davidi*, *E. sinensis*; *Berberidopsis corallina*; papillae are present on the upper side of the leaf in: *Berberis actinacantha*, *B. acuminata*, *B. agapatensis*, *B. asiatica*, *B. crispa*, *B. ferruginea*, *B. flexuosa*, *B. laxiflora*, *B. levis*, *B. lycium*, *B. Weddellii*; *Mahonia Andrieuxii* (Hook. et Arn.), *M. Fremontii*, *M. haematocarpa*, *M. pumila*, *M. subintegrifolia*, Fedde, *M. trifolsiolata*. The papillae found in *Berberis guilache*, *B. ovata*, and *B. tolimensis* are of a specially curious type; they are united into groups and are situated at the margins of the individual epidermal cells.

We may enumerate here separately from the foregoing list those species of *Berberis* (*Euberberis*) in which C. K. Schneider mentions the occurrence of a papillose epidermis in the leaf. Papillae are present (they were only taken into account by Schneider when they were evident in a surface-view of the epidermis) on the lower side of the leaf in: *Berberis afghanica*, Schn., *B. agapatensis*, Lechl., *B. armata*, Cit., *B. aurahuacensis*, Lem., *B. asiatica*, Roxb., *B. brachybodria*, Gay, *B. bumeliaefolia*, Schn., *B. buxifolia*, Lam. var. *papillosa*, Schn., *B. chilensis*, Gill., *B. chinboensis*, Schn., *B. chitria*, Lindl. var. *sikkimensis*, Schn. (slight papillae), *B. concinna*, Hook. f., *B. corymbosa*, Hook. et Arn., *B. cuneata*, DC., *B. dasystachya*, Maxim., *B. diaphana*, Maxim., *B. elegans*, Schn., *B. empetrifolia*, Lam., *B. flexuosa*, R. et P., *B. Forskaliana*, Schn. (not at all points), *B. garhwalensis*, Schn. (more or less marked), *B. grandiflora*, Turcz., *B. Hallii*, Hieron., *B. Jaeschkeana*, Schn. (not always distinct), *B. ignorata*, Schn., *B. integerrima*, Bge. var. *eriwanensis*, Schn. and var. *typica*, Schn., *B. kaschgarica*, Rupr., *B. Köhneana*, Schn., *B. kumaonensis*, Schn., *B. latifolia*, R. et P., *B. linearifolia*, Phil., *B. lutea*, R. et P., *B. lycium*, Royle, *B. macrosepala*, Hook. f. et Th., *B. Moritzii*, Hieron., *B. nigricans*, O. Ktze., *B. nummularia*, Bge. var. *pyrocarpa*, Schn., *B. pallens*, Franch., *B. Pearcei*, Phil., *B. Petitiana*, Schn., *B. phyllacantha*, Rusby, *B. polyantha*, Hemsl., *B. psilopod.*, Turcz., *B. rariflora*, Lechl., *B. rectinervia*, Rusby, *B. Soulieana*, Schn., *B. Thomsoniana*, Schn., *B. Thunbergii*, DC. (in part), *B. tinctoria*, Lesch., *B. trigona*, Kze., un-

in *Berberis marginata*, whilst characteristic thickenings of the outer wall, in the form of a network of ridges, are present in those species of *Mahonia*, which Fedde includes in the Aquifoliatae and Paniculatae. In certain species of *Berberis* and *Mahonia* [1] a parenchymatous hypoderm, mostly with thin walls, occurs beneath the upper epidermis; in species of *Berberis* and *Mahonia* [2] with thick evergreen leaves a still more widely distributed feature is a hypoderm composed of sclerenchymatous fibres and situated likewise beneath the upper epidermis [3]. The **stomata** are found on the upper as well as on the lower side of the leaf only in certain species of *Berberis* and *Leontice* [4]. Subsidiary cells can only be said to be present in *Berberidopsis*, where each pair of guard-cells is surrounded by a multiseriate ring of rather small epidermal cells. Citerne mentions the occurrence of lobe-like appendages at the ends of the guard-cells in *Caulophyllum*, *Epimedium Davidi* and *E. sinense*. For the water-pores of *Podophyllum* see Spanjer, loc. cit. In certain species of *Berberis* and *Mahonia* [5] one or more layers of the spongy tissue have thicker walls and scanty chlorophyll, so that they function as mechanical tissue; in some cases they are differentiated like a hypoderm.

As regards the **veins** of the leaf we may mention that Citerne attributes generic importance to the number of vascular bundles in the principal veins (one bundle in *Caulophyllum*, *Jeffersonia*, *Leontice*; several in *Achlys*, *Berberis* incl. *Mahonia*, *Diphylleia*, *Epimedium*, *Nandina*, *Podophyllum*), and to the occurrence of groups of sclerenchymatous fibres situated at the margin of the leaf and sometimes developed in connexion with a marginal vascular bundle (only in *Berberis* incl. *Mahonia*, *Epimedium*, *Nandina*). The groups of sclerenchymatous fibres accompanying the vascular bundles of

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named species belonging to the section Truxillenses, *B. umbellata*, Wall. (rather distinct), *B. variiflora*, Schn., *B. verticillata*, Turcz., *B. virescens*, Hook. f., *B. virgata*, R. et P., *B. vitellina*, Hieron., *B. Wawrana*, Schn., *B. Wightiana*, Schn. (in most cases), *B. yunnanensis*, Franch.

[1] These species are: *Berberis agapatensis*, *B. armata*, *B. conferta*, *B. flexuosa*, *B. horrida* pro parte, *B. loxensis*, *B. multiflora*, *B. paniculata*, *B. Wallichiana* pro parte, *B. Weddellii*; *Mahonia Hartwegii* (Benth.).

[2] The following species: *Berberis actinacantha*, Mart., *B. brachybotrya*, *B. carinata*, *B. chilensis*, *B. Claussenii*, *B. coriacea*, *B. Darwinii*, *B. Darwinii* × *empetrifolia*, *B. diffusa*, *B. empetrifolia*, *B. ferox*, *B. ferruginea*, *B. Grisebachii*, *B. heterophylla*, *B. horrida*, *B. ilicifolia*, *B. insignis*, *B. laurina*, *B. levis*, *B. litoralis*, *B. Negeriana*, Tischl., *B. Potanini*, *B. pruinosa*, *B. ruscifolia*, *B. saxicola*, *B. serrato-dentata*, *B. spinulosa*, *B. Valdiviana*, *B. virgata*; *Mahonia eurybracteata*, Fedde, *M. Fortunei*, Lindl., *M. Fremontii* (Torr.), *M. haematocarpa* (Woot.), *M. japonica*, Thunb., *M. nepalensis*, DC., *M. nervosa*, Nutt., *M. polyodonta*, Fedde, *M. trifoliata* (Moric.), these being the species belonging to the sections which Fedde names Longibracteatae and Horridae.

[3] C. K. Schneider mentions the occurrence of hypoderm in the following species without giving further details: *Berberis actinacantha*, Mart. (almost invariably), *B. agapatensis*, Lechl., *B. barandana*, Vid., *B. brachybodria*, Gay, *B. chilensis*, Gill., *B. conferta*, Kth., *B. cuneata*, DC., *B. Darwinii*, Hook., *B. divaricata*, Rusby, *B. empetrifolia*, Lam., *B. Griffithiana*, Schn., *B. Hallii*, Hieron., *B. ilicifolia*, Forst., *B. insignis*, Hook. f. et Th., *B. laurina*, Billbg., *B. linearifolia*, Phil., *B. litoralis*, Phil., *B. loxensis*, Benth., *B. lutea*, R. et P., *B. paniculata*, Juss., *B. Pearcei*, Phil., *B. pectinata*, Hieron., *B. phyllacantha*, Rushy, *B. pindilicensis*, Hieron., *B. psilopoda*, Turcz., *B. rariflora*, Lechl., *B. rectinervia*, Rushy, *B. ruscifolia*, Lam., *B. Schwerini*, Schn., *B. Sellowiana*, Schn., *B. Soulieana*, Schn., *B. trigona*, Kunze, *B. valdiviana*, Phil., *B. variiflora*, Schn., *B. verticillata*, Turcz., *B. virgata*, R. et P., *B. Wallichiana*, DC., *B. Warscewiczii*, Hieron., *B. Wawrana*, Schn., *B. Wettsteiniana*, Schn.

[4] According to C. K. Schneider, they are present in large numbers on the upper side in the following species only: *Berberis aetnensis*, Presl, *B. australis*, Moris var. *Hackeliana*, Schn., *B. Boissieri*, Schn., *B. crataegina*, DC., *B. cretica*, L., *B. integerrima*, Bge., *B. kaschgarica*, Rupr.

[5] The following species: *Berberis asiatica*, *B. brachybotrya*, *B. carinata*, *B. chilensis*, *B. Claussenii*, *B. conferta*, *B. coriacea*, *B. diffusa*, *B. ferox*, *B. Goudotii*, *B. ilicifolia*, *B. insignis*, *B. levis*, *B. pruinosa*, *B. saxicola*, *B. Valdiviana*; *Mahonia eurybracteata*, *M. Fortunei*, *M. japonica*, *M. nepalensis*, *M. nervosa*, *M. polyodonta*, i.e. species belonging to the section Longibracteatae of Fedde.

the smaller veins are often strongly developed, and in many species of *Berberis* and *Mahonia* cause the veins to be vertically transcurrent.

Regarding the mode of deposition of **oxalate of lime** we may add the following information. The clustered crystals occasionally (e.g. in the pith of *Mahonia lanceolata* and *M. pinnata*) exhibit a sphaerocrystalline structure. The prismatic crystals of unknown chemical composition discovered by Vesque have also been observed by Fedde in *Mahonia nepalensis* and by Citerne in *Berberis cretica, B. Grisebachii* and *B. levis*.

The glandular **hairs** of *Epimedium* have already been mentioned above. Uniseriate hairs, composed of strongly thickened cells (and likewise observed by Citerne), are present in *Epimedium acuminatum* and *E. sinense*; they consist of a few short stalk-cells and a long terminal cell, which is specially thick-walled and pitted. Structures resembling lenticels are present in large numbers in *Berberis Feddeana*, Schn., where they cause brown dots on the lower side of the leaf; in other species of *Berberis* (e.g. *B. canadensis*, Mill.) they are not abundant, nor are they always present.

For the structure of the leaf-spines see Mittmann, Citerne, and Lothelier, ll. cc.

3. Structure of the Axis. According to Citerne, the herbaceous members of the Order (*Achlys, Caulophyllum, Diphylleia, Epimedium, Jeffersonia, Leontice, Podophyllum*) have a normal ring of **vascular bundles** in their subterranean axis, like that in the woody species. In *Achlys, Diphylleia* and *Podophyllum*, besides the normal vascular bundles there are others situated in the primary cortex and composed mainly of sclerenchyma; these cortical bundles originate in the scale-leaves clothing the rhizome, and, according to Tischler, they finally pass into the normal ring of bundles. On the other hand, in the subaerial portions of the axis among the herbaceous species there is a tendency for the vascular bundles to show a scattered arrangement, or to be grouped in two or more rings [1]. This anomaly is specially pronounced in *Diphylleia, Leontice* and *Podophyllum*; in *Epimedium*, according to Citerne, there are two rings of bundles, whereas, according to Tischler, the presence of two rings can only be inferred; in *Achlys* Tischler records two rings of bundles, or a single ring of dovetailing bundles. In the same way the other genera (including *Ranzania* according to Tischler) have for the most part vascular bundles of two sizes, and here also two rings of bundles may be supposed to be present. A typical scattered arrangement of the bundles or their disposition in two or more rings is only found when the number of vascular bundles is sufficiently large. In the case of *Podophyllum* Tischler has shown that the inner vascular bundles are of the nature of leaf-traces. We may add that the soft bast in *Podophyllum*, like that of the Monocotyledons, contains only sieve-tubes and companion-cells, and no bast-parenchyma.

Our knowledge of the structure of the **cortex** in the Berbereae has also been extended. In most cases the pericycle comprises a continuous or interrupted ring of bast-fibres, or isolated groups of bast-fibres. Pericyclic bast-fibres (which we may note are frequently septate by means of thin transverse walls) are only wanting in the subterranean axes of the herbaceous forms (with the exception of *Epimedium*) and in the subaerial stem of *Leontice altaica*. In the subaerial axes of *Epimedium*, and of *Nandina, Mahonia Fortunei* and *M. japonica*, two zones of bast-fibres are found in the pericycle (Citerne); in *Mahonia Ehrenbergii*, Kunze, the pericycle contains a composite and continuous ring of sclerenchyma (Fedde), as in the Lardizabaleae. In *Berberis* and

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[1] Perrot's statement (Tissu criblé, Thèse, Paris, 1899, p. 141) that secondary bundles of wood and bast occur in the primary cortex of the Lardizabaleae is incorrect.

Mahonia the bast occasionally includes bast-fibres, which are sometimes septate or merge into short sclerenchymatous elements. The cork originates in various positions; either in a layer of the primary cortex (in some cases the subepidermal layer), or the pericycle. The former has been shown to be the case in: *Berberis ulicina*; those species of *Mahonia* of the section Paniculatae, which have been investigated with regard to this character; the subterranean portions of the axis in *Caulophyllum, Diphylleia, Jeffersonia* (subepidermal), *Leontice, Podophyllum* (subepidermal); and *Berberidopsis*. The cork arises in the pericycle in most species of *Berberis*, in *Mahonia* pro parte, and in the rhizomes of *Achlys* and *Epimedium*.

For the structure of the **root** in the Berbereae see also Citerne, loc. cit.

Literature: Nanke, Axen bei dikotyl. Holzpfl., Diss., Königsberg, 1886, p. 35.—Mittmann, Pflanzenstach., Verh. bot. Ver. Brandenburg, 1889, p. 54.—Citerne, Berbéridées et Erythrospermées, Thèse, Paris, 1892, 161 pp. and 8 pl.—Lothelier, Épines, Thèse, Paris, 1893.—Schwabach, Bot. Centralbl. 1898, iv, p. 359.—Spanjer, Wasserapparate, Bot. Zeit., 1898, i, p. 55.—Holm, *Podophyllum*, Bot. Gazette, 1899, pp. 419–31.—Köhne, Anatom. Merkmale bei *Berberis*-Arten, in Wittmack, Gartenflora, 1899, pp. 19, 39 and 68 et seq.; see also Mitteil. deutsch. dendrolog. Gesellsch. 1899, p. 54.—Koedler, Assimilator. Gewebesyst., Diss., Freiburg i. Schw. 1899, p. 37.—Fedde, Monographie d. Gatt. *Mahonia*, in Engler, Bot. Jahrb., xxxi, 1901, pp. 30–133.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 49 and 53.—Petersen, Vedanatomi, 1901, p. 42.—Simon, in Ber. deutsch. bot. Gesellsch. 1902, p. 238.—Tischler, Berberidaceen u. Podophyllaceen, in Engler, Bot. Jahrb., xxxi, 1902, p. 596 et seq.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 116.—C. K. Schneider, *Berberis* (*Euberberis*), Bull. de l'Herbier Boissier, sér. 2, v, 1905, pp. 33 et seq.—Piccioli, Legnami, Bull. Siena, 1906, p. 169.—[For additional literature, see p. 1169.]

NYMPHAEACEAE (pp. 47–51).

2. STRUCTURE OF THE LEAF. It is characteristic of the **stomata** of *Nymphaea*, and also of those of *Euryale, Nuphar* and *Victoria*, that the closing of the pore is not effected by contact of the arched ventral walls of the guard-cells, but by more or less complete approximation of the external cuticular ridges of the latter (Haberlandt). The branched sclerenchymatous cells (internal hairs, trichoblasts) found in the genera *Nymphaea, Nuphar, Victoria* and *Euryale* have recently been thoroughly investigated by Gürtler. Their form varies greatly, even within the limits of the same species. Besides the stellate **idioblasts** and those of girder-like form showing one-sided development and resembling hairs, other specially noteworthy forms are the H-shaped elements resembling the spicular cells of the Aroideae and occurring in the peripheral portions of the petiole and peduncle of *Nymphaea*. The crystals of oxalate of lime on the idioblasts of *Nymphaea* are sometimes reduced in number; according to Gürtler, p. 19 (but not quite in accordance with p. 42), similar crystals apparently occur in *Victoria regia* also; in *Nymphaea* and *Nuphar* the walls of the trichoblasts bear pits where they are in contact with the neighbouring cells. According to Gürtler, the trichoblasts have a purely mechanical function.

Other structures which may, according to Gürtler, be classed with these unicellular internal hairs are multicellular intercellular structures resembling shaggy hairs; they consist of several rows of cells with thick pitted walls, attain a length of ·02–·1 mm., and are terminated by a stellate cell enclosing a large clustered crystal. These hairs are either unbranched or branched, and in the latter case each branch terminates in a cell with a clustered crystal. They occur in *Nelumbium speciosum*, where they accompany the hair-like cells containing clustered crystals previously mentioned, and are situated in the intercellular spaces in the neighbourhood of the diaphragms, which in this species are specially lacunar; they serve as a mechanical support to these diaphragms. Regarded developmentally they are emergences, since they arise from the two outermost cell-layers of the wall of the intercellular canal.

According to Gürtler, structures similar to those forms of internal hairs described as false diaphragms by Trécul (see the previous statements on p. 49) are also found in *Nymphaea capensis* and other species, as well as in *Euryale ferox*. The hair-like structures found in *Brasenia*, mentioned and figured in the earlier part of this work (after Schrenk), are, according to Gürtler, probably of a pathological nature, since they have not been observed under normal conditions. Intercellular hairs of a pathological nature are moreover quite common in the Nymphaeaceae; for this point, see Gürtler, loc. cit., p. 54 et seq.

With reference to the systematic value of the air-canals in the petiole see Conard, loc. cit.

3. Structure of the Axis. According to Van Tieghem and Schoute, astely is of almost universal occurrence in the rhizomes of the Nymphaeaceae. *Nelumbium* alone has a general endodermis around the central cylinder. According to Gwynne-Vaughan, polystely (with twelve or more 'root-bearing steles') is also found in the rhizome of *Victoria regia* and certain species of *Nymphaea* (locally beneath the points of insertion of the leaves).

Note.—We may mention that, according to Hewitt, the Nymphaeaceae are the only Order of Dicotyledons in which the root-hairs arise from special cells, noticeable as idioblasts even during the differentiation of the epidermis of the root, this being analogous to what has been observed in very many Monocotyledons.

Literature: Costantin, Tiges d. pl. aquat., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 et seq. and pl. 17.—Haberlandt, Spaltöffn. d. Schwimmpfl., Flora, 1887, p. 102.—Mittmann, Pflanzenstacheln, Verh. bot. Ver. Brandenburg, 1889, p. 63.—Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 32-5.—Gwynne-Vaughan, Morph. and anat. of Nymphaeaceae, Transact. Linn. Soc. Bot., 1897, pp. 287-99 and pl. 21, 22.—Wollenweber, Anat. d. Schwimmbl., Diss., Freiburg i. Br., 1897, pp. 23-6 and 32, 33.—Weinrowsky, Scheitelöffn. bei Wasserpfl., Diss., Berlin, 1898, p. 35.—Thomas, Feuilles sout., Thèse, Paris, 1900.—Masters, Air-canals in the stalks of Nymphaeaceae, Journ. Roy. Hortic. Soc., xxvi, 1901-2, pp. 840-3.—Knothe, Unbenetzbare Bl., Diss., Heidelberg, 1902, p. 16.—Schoute, Stelärtheorie, 1903, p. 115.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., H. 61, 1904, p. 55.—Leavitt, Trichomes of the root, Proceed. Boston Soc. Nat. Hist., xxxi, 1904, p. 300.—Pizzetti, Local. dell' alcaloide nel *Nuphar*, etc., Malpighia, 1904, pp. 106-9.—Conard, Waterlilies, Washington, 1905, pp. 27-77.—Gürtler, *Intercellulare Haarbild., Diss., Berlin, 1905, 91 pp.*—[*Montemartini*, Sist. mecc. della *Victoria regia*, Atti Ist. bot. Pavia, 1905, 5 pp. and 3 tab.]—[Chifflot, Anat. comp. des *Barclaya longifolia* et *B. Mottleyi*, Bull. Soc. sc. nat. Saône-et-Loire, 1906.]—Géneau de Lamarlière, Membr. cut. des pl. aqu., Revue gén. de bot., 1906, p. 289 et seq.

SARRACENIACEAE (pp. 51-54).

Fenner's[1] recent investigations include *Sarracenia flava*, L., in which they deal with the nectarial glands found on the under side of the lid and around the entrance to the pitcher, the development of the hairs in the 'eel-trap-zone,' and the fourth or lowermost zone of the pitcher, which is regarded as the absorptive region. The nectarial glands are of epidermal origin, having a patelliform depression at the apex and resembling the glands of the pitcher in structure. The absorptive zone has an epidermis of peculiar structure, the cells having undergone division, though the daughter-cells are only bounded by incomplete walls in the form of ridges. Without further investigation I cannot accept Fenner's interpretation that we are dealing with simple epidermal cells, which have become segmented into a number of 'niches' by means of ridges of cellulose and include 'several nuclei.'

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[1] Fenner, Anat., Entwicklungsgesch. u. Biol. d. Laubbl. u. Drüsen einiger Insectivoren, Diss., Zürich, 1904, pp. 21-7 and Tab. ix and xxi (also Flora, 1904).—See also: Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., H. 61, 1904, p. 63.—[Macfarlane, *Sarracenia Catesbaei*, Contrib. Bot. Lab. Philadelphia, ii, 1904, p. 426 et seq.]—Forrest Shreve, *Sarracenia purpurea*, Bot. Gaz., xlii, 1906, pp. 118-23.

PAPAVERACEAE (pp. 54–56).

3. STRUCTURE OF THE AXIS. Astely is found in *Chelidonium majus* (Schoute).

Literature: E. Schmidt, Milchr., Bot. Zeit., 1882, p. 445.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskr., xix, 1895, p. 219 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iii, p. 474.—Minden, Wassersec. Org., Bibl. bot., H. 46, 1899, p. 34.—Thomas, Feuilles sout., Thèse, Paris, 1900.—Molisch, Milchsaft u. Schleimsaft, 1901, p. 71 et seq.—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 14.—Schoute, Stelärtheorie, 1903, p. 116.—Theorin, Växttrichom., Arkiv for Bot., i, 1903, p. 171.—Kniep, Bedeut. d. Milchsaftes, Flora, 1905, p. 176 et seq.—Mayus, Milchr. in den Bl., Beih. bot. Centralbl., xviii, Abt. 1, 1905, pp. 276–8.—Sarton, Rech. exp. sur l'anat. des pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 25–32 (*Chelidonium*).—[Faltis, Opiumalkaloide, Pharm. Post., 1906, n. 31, 32; abstr. in Bot. Centralbl., civ, p. 61.]

FUMARIACEAE (pp. 56–58).

Zsak Zoltan has recently met with unicellular finger-shaped trichomes in specimens of *Corydalis cava* and *C. solida*, two species which he regards as varieties.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 96 et seq.—Jost, Zerklüft. einiger Rhiz. u. Wurz., Bot. Zeit., 1890, p. 469 et seq. (*Corydalis*).—Thomas, Feuilles sout., Thèse, Paris, 1900.—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 15.—Zsak Zoltan, in Magyar Bot. Lapok, 1904, 4 pp.—[Haberlandt, Sinnesorg., ii Aufl., 1906.]

CRUCIFERAE (pp. 58–67).

2. Schweidler's recent investigations on the **myrosin-cells** found in the foliage-leaves of the Cruciferae contain the following statements, which we may add to the information given on pp. 60–62. The earlier statement (p. 60) regarding the absence of chlorophyll-grains in the myrosin-cells is incorrect, since Schweidler found chloroplasts in the secretory cells of the assimilatory tissue in those species which he subjected to a detailed examination. According to Schweidler, the local distribution and the differentiation of the idioblasts in the sepals, petals and the valves of the pod are essentially the same as in the foliage leaves. The presence or absence of idioblasts is probably a character of generic value. In those cases in which no myrosin-cells have been found in certain species of a genus generally possessing these elements, this is probably due to a reduction of the secretory cells, which has hitherto rendered it impossible to recognize them. Closely related species possess albuminous cells agreeing in their local distribution, size, shape, &c. Schweidler distinguishes between 'idioblasts of the vascular bundles,' which are mostly prosenchymatous, and 'idioblasts of the mesophyll,' which are parenchymatous elements containing chlorophyll and showing little or no difference from the ordinary cells of the mesophyll; he subdivides the idioblasts of the vascular bundles into 'idioblasts of the phloem-sheath' and 'idioblasts of the parenchyma-sheath.' According to the same authority another point of systematic importance is to be found in the presence or absence of special albuminous contents in the guard-cells of the stomata in those species, which have no idioblasts.

The genus *Arabis* has been made the subject of detailed investigation by Schweidler, his results being as follows. In the species of the section *Turritis*, L. the idioblasts are present in the phloem-sheath only, in the species of the section *Cardaminopsis*, Boiss. they occur both in the phloem-sheath and in the parenchyma-sheath, in those of the sections *Pseudarabis*, C. A. Mey. and *Turritella*, C. A. Mey. the idioblasts are situated in the mesophyll, and in those of the section *Euarabis* there are only special albuminous contents in the guard-cells, whilst in some few species no idioblasts were recognizable. In consequence of these results and from a consideration of other characters Schweidler comes to the conclusion that the genus

Arabis must be provisionally restricted to the sections *Euarabis*, *Pseudarabis* and *Turritella*, whilst the section *Cardaminopsis* should be included in *Cardamine*, and *Turritis* raised once more to the rank of an independent genus.

The same features are moreover of value in connexion with the subdivision of the Cruciferae, if one studies the affinities of the genera having idioblasts in the mesophyll only (Exo-idioblastae), or idioblasts in the vascular bundles only (Endo-idioblastae), or both kinds of idioblasts (Hetero-idioblastae).

The Exo-idioblastae include the following genera: *Lunaria*, *Vesicaria*, *Schivereckia*, *Peltaria*, *Petrocallis*, *Draba*, *Cochlearia* (Alyssineae); *Thlaspi*, *Teesdalia* (Thlaspideae); *Anastatica* (Anastaticeae); *Cakile*, *Chorispora* (Cakilineae); *Goldbachia* (Anchonieae); *Brassica*, *Sinapis*, *Moricandia*, *Diplotaxis*, *Eruca* (Brassiceae); *Vella*, *Carrichtera*, *Succovia* (Velleae); *Crambe*, *Rapistrum*, *Raphanus* (Raphaneae); *Bunias* (Buniadeae); *Braya*, *Arabis* sens. strict. (Arabideae); *Alliaria*, *Conringia* (Sisymbrieae). The Endo-idioblastae include: *Cheiranthus*, *Nasturtium*, *Barbarea*, *Turritis*, *Arabis* Sect. *Cardaminopsis*, *Cardamine*, *Dentaria* (Arabideae); *Malcolmia*, *Hesperis*, *Sisymbrium*, *Erysimum* (Sisymbrieae); *Camelina* (Camelineae); *Senebiera*, *Lepidium*, *Aethionema* (Lepidineae); *Capsella*, *Biscutella* (Thlaspideae); *Heliophila* (Heliophileae). The Hetero-idioblastae include: *Iberis*; *Lepidium Draba*; *Isatis Myagrum* (Isatideae).

Mardner also mentions the occurrence of myrosin-cells in *Pringlea antiscorbutina*, R. Br.

According to Bouygues, the **petiole** of the Cruciferae is distinguished by the presence of 'faisceaux rayonnés,' which have a characteristic mode of development. The vascular bundles of the petiole are arranged in a ring, and are embedded in a parenchymatous tissue, the cells of which differ from the parenchyma of the ground-tissue in having smaller lumina and thicker walls. The entire ring of vascular bundles, together with the small-celled parenchyma, develops from a single procambial strand, in which secondary procambial bundles become differentiated and give rise to the individual vascular bundles.

Regarding the anomalous strands of soft bast in the rhizome and root of *Cochlearia Armoracia*, see also Viret, loc. cit.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 98 et seq.—Costantin, Tiges aér. et sout. d. pl. aquat., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 et seq., and pl. 14–16.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskr., xix, 1895, p. 219 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl. 1897, iii, p. 475.—Leisering, Interxyl. Leptom, Diss., Berlin, 1899, p. 28.—Anheisser, Arunkoide Blattspreite, Diss., Jena, 1900, pp. 18, 19.—Paulesco, Struct. anat. des hybrides, Thèse, Genève, 1900, p. 63 (*Dentaria*).—Schleichert, Xerophyten bei Jena, Naturwiss. Wochenschr., 1900, p. 446 (*Thlaspi*).—Thomas, Feuilles sout., Thèse, Paris, 1900.—Veba, Anat. d. Axen von *Alyssum calycinum*, Oesterreich. bot. Zeitschr. 1901, pp. 225–33.—Bouygues, Pétiole, Thèse, Paris, 1902, p. 31 et seq.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 57, 58 (*Cheiranthus*[1]).—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 15.—Mardner, Phan.-Veg. der Kerguelen, Diss., Basel, 1902, pp. 8–14 (*Pringlea*).—[*Armari, Piante della reg. medit., Ann. di bot., i, 1903, p. 17 et seq. (Iberis).*]—Theorin, Växttrichom., Arkiv för Bot., i, 1903, p. 170 and iv, n. 18, 1905, pp. 17, 18.—[Boodle, Wallflower, New Phytol., iii, 1904, p. 39; abstr. in Bot. Centralbl., xcv, p. 504.]—Chrysler, Strand plants, Bot. Gazette, xxxvii, 1904, p. 461 et seq. (*Cakile*).—Süssenguth, Beh.-Verh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, pp. 19, 20.—Viret, Liaisons du phloème méd. etc., Institut bot. Genève, 1904, pp. 36–45.—Schweidler, Eiweisszellen d. Crucif., Ber. deutsch. bot. Gesellsch., 1905, pp. 274–85 and Taf. xii.—[For additional literature, see p. 1170.]

CAPPARIDEAE (pp. 67–77).

1. Under the general Review of Anatomical Features we may add that crystalloids are occasionally present (in cells of the ground-tissue and epidermis of the petiole of *Boscia*) in the form of small rhombohedral, octahedral or rounded crystalline bodies.

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[1] The statement that glandular hairs are present in *Cheiranthus scoparius* appears questionable to me.

2. Structure of the Leaf. In connexion with a monographic revision of *Boscia* Pestalozzi made a thorough examination of the structure of the leaf in this genus. The most characteristic feature of the genus is the occurrence in the mesophyll of sclerenchymatous cells elongated in the same direction as the palisade-tissue ; these elements are situated beneath the epidermis on both sides of the leaf, and where they come in contact with the epidermis they exhibit either a bulbous (*B. angustifolia*, Rich.) or a somewhat T-shaped (*B. rotundifolia*, Pax, &c.) enlargement, or a more or less abundant ramification. The thickness of their walls varies greatly. In some cases these elements, like the sclerenchymatous cells of certain species of *Capparis*, may even penetrate between the epidermal cells, and thus form part of the surface of the leaf. The structure of the leaf in *Boscia* is bifacial or centric ; the stomata are either restricted to the lower surface or are found on both sides of the leaf. No hypoderm is present. On the other hand storage tracheids (described by Pestalozzi as 'sclereids with a lobed form') occur in the spongy tissue. The vascular bundles of the smaller veins are provided with hard hast and are embedded. The hairy covering consists only of unicellular clothing hairs of varied length ; in *B. corymbosa*, Gilg. these hairs appear like finger-shaped papillae. For the remaining features of the leaf-structure see the work cited below. Large solitary crystals of oxalate of lime (cf. Syst. Anat., p. 71) also occur in the axis of *Cadaba* ; they are situated in the stone-cells of the pericycle.

The thorns of *Capparis spinosa*, which are interpreted as stipules, contain neither vascular bundles nor terminations of bundles (Lothelier).

3. Structure of the Axis. The cork in *Cadaba glandulosa*, Forsk. also arises subepidermally. In this species the primary cortex contains groups of stone-cells, and the pericycle exhibits a composite and continuous ring of sclerenchyma.

Literature: Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 50, 51.—Lothelier, Épines, Thèse, Paris, 1893, pp. 35 and 46.—Pestalozzi, *Boscia*, Bull. de l'Herbier Boissier, 1898, App. iii ; also Diss., Zürich, 152 pp. and 13 pl.—Urspung, *Cadaba glandulosa*, Ber. deutsch. bot. Ges., 1901, pp. 501–8 and Tab. xxix.—[Moll and Janssonius, Mikrographie d. Holzes, Leiden, 1906, pp. 175–92 (*Capparis, Crataeva*).]—[Holtermann, Einfluss d. Klimas, 1907, p. 106 (*Capparis, Maerua*).]

RESEDACEAE (pp. 77–79).

Morstatt's recent investigations deal with only a few species of *Reseda*. The discovery of oxalate of lime in the form of small crystals in the pith of *Reseda odorata* is specially noteworthy.

Other points of importance are as follows. Large vesicular papillae with transitions to simple unicellular blunt hairs are borne by the epidermis of the stem in *R. lutea* ; on the leaf the papillae are restricted to the margin. The pericycle in the stem of *Reseda* includes groups of bast-fibres. The structure of the wood in *Reseda* exhibits the same features as in *Ochradenus*.

The basal appendages ('denticuli basilares') of the leaves of *Reseda* exhibit various types of structure ; in *R. lutea* they have a distinct palisade-like epidermis, which secretes mucilage ; in no case do they contain a vascular bundle.

Literature: J. Müller, Monogr. de la famille des Réséd., Zürich, 1857, p. 11 et seq. and Tab. i–iii.—[Tognini, Stomi, Atti. Ist. bot. Pavia, 1894.]—Morstatt, Beitr. z. Kenntn. d. Resed., Diss., Heidelberg, 1903, 64 pp.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 109.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 20.

CISTINEAE (pp. 79–82).

With reference to the **hairy covering** (p. 80) we may add, on Süssenguth's authority, that tufted hairs like those found in *Cistus creticus* (Syst. Anat., Fig. 21, *B*) also occur in *Helianthemum nanum*, but not in *H. vulgare* and *H. polifolium*.

Regarding the structure of the **axis** (cf. p. 82) the following data may be quoted from Piccioli's investigations, which deal with the four genera of the Order. In the wood, medullary rays are not present in *Lechea*, whilst in the remaining genera they are narrow and mostly uniseriate. As a rule the bulk of the wood is composed of prosenchyma with bordered pits; in the species of *Helianthemum* belonging to the section *Eriocarpum*, however, the tracheids are replaced by mechanical elements. Wood-parenchyma only occurs in relatively small amount. The region in which the first layer of cork is produced varies, being the epidermis in *Cistus* and *Helianthemum* § *Lecheoides*, the subepidermal layer of cells in *Lechea*, *Helianthemum* § *Halimium* and *Euhelianthemum*, a more or less deeply situated layer of the primary cortex in *Helianthemum* § *Macularia*, *Brachypetalum* pro parte, *Eriocarpum*, *Fumana* pro parte and *Pseudocistus*, the endodermis in § *Brachypetalum* pro parte, and lastly the cell-layer situated on the inner side of the bast-fibres of the pericycle in *Hudsonia* and § *Fumana* pro parte. The endodermis is seldom distinctly differentiated; it constitutes aqueous tissue in *Helianthemum polifolium* and *H. salicifolium*. The outer portion of the primary cortex is often collenchymatous. The pericycle in species of all the genera includes a ring of fibres, or isolated groups of bast-fibres; in certain species of *Helianthemum* the bast-fibres are scanty or absent. In *H. guttatum* the pith is differentiated as aqueous tissue. It remains to mention that in all the genera oxalate of lime occurs in the form of clustered crystals; and that additional solitary crystals have only been observed in different parts of the axis in the species of *Helianthemum* belonging to the section *Eriocarpum* (*H. kahiricum* and *H. sessiliflorum*).

Literature[1]: Gauchery, Hybrides dans le genre *Cistus*, Assoc. franç. Besançon, 1893, i, p. 238, and ii, pp. 534–41.—Schubert, Parenchymscheiden, Bot. Centralbl. 1897, iv, p. 16.—Paulesco, Struct. anat. des hybrides, Thèse, Genève, 1900, p. 75 (*Cistus*).—Clauditz, Blattanatomie canar. Gew., Diss., Basel., 1901, pp. 12, 13 (*Cistus*).—Gauchery, in Assoc. franç. Ajaccio, 1901, ii, ed. 1902, pp. 408–13 (*Helianthemum halimifolium* x *Cistus salvifolius*).—Petersen, Vedanatomi, 1901, p. 43.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 102.—Grosser, Cistaceae, in Pflanzenreich, H. 14, 1903, pp. 3–4.—Piccioli, Legno e corteccia delle Cistin., Nuov. Giorn. bot. Ital., N. S., xi, 1904, pp. 472–504.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, pp. 20–22.—Sarton, Anat. d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 39–43 (*Helianthemum*).—Piccioli, Legnami, Bull. Siena, 1906, p. 167.—[For additional literature, see p. 1169.]

VIOLARIEAE (pp. 82–86).

Section 2. An undetermined Peruvian species of *Viola* (*Viola* 62) investigated by Weberbauer has a papillose epidermis on the upper side of the leaf; on the same side there is also a strongly projecting network formed by strands of tissue containing 2–3 layers of palisade-cells showing a fan-like arrangement.

With reference to the teeth on the margin of the leaf (p. 85) we may add that they secrete lime in some species of *Viola* (e.g. *V. scandens*, Willd., according to Triana et Planchon, Prodr. Flor. Nov. Granat., Ann. sc. nat., sér. 4, t. xvii, 1862, p. 121, and *V. Lindeniana*, Turcz., Tonduz, n. 2123, Costarica).

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[1] Gerber's paper (Ét. anat., phys. et biol. sur les Cistes de Provence, Annuaire Fac. Sc. Marseille, 1899) only deals with the reproductive organs.

SECTION 3. According to Pitard, a composite and continuous ring of sclerenchyma in the pericycle is also developed in '*Ionidium salicifolium*' and species of *Alsodeia*.

Literature: G. Kraus, Inulin bei Viol., Sitz.-Ber. naturf. Gesellsch., Halle, 1880, p. 6; see also Barnes, in Pharm. Journ. and Transact., 1884, p. 515, and Beauvisage, in Bull. trimestr. Soc. bot. de Lyon, 1888, pp. 12 and 39.—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 102 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl. 1897, iv, p. 17.—[Hartwich, Falsche Ipecacuanhawurz., Schweizer. Wochenschr. f. Chemie etc., 1899, n. 48; abstr. in Just, 1900, ii, p. 28, Inulin !].—Paulesco, Struct. anat. des hybrides, Thèse, Genève, 1900, p. 70 (*Viola*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 70.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 55, 56.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., H. 61, 1904, pp. 61–3.—Sarton, Rech. exp. sur l'anat. des pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, p. 86 (*Viola*).—Süssenguth, Behaarungsverh. der Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 22.—Theorin, Växttrichom., Arkiv för Bot., iii, n. 5, 1904, p. 18; see also loc. cit., iv, n. 18, 1905, p. 14.—Weberbauer, Veget. der Hochanden Perus, in Engler, Bot. Jahrb., xxxvii, 1905, p. 88.—[Moll and Janssonius, Mikrographie d. Holzes, Leiden, i, 1906, pp. 193 7 (*Alsodeia*).]

CANELLACEAE (pp. 86–87).

2. STRUCTURE OF THE LEAF. In *Canella alba*, P. Browne, *C. obtusifolia*, Miers, and *Cinnamodendron macranthum*, Baill. the mesophyll contains no typical palisade-tissue. According to Parmentier, clustered crystals are found in the epidermis, where they occur in every cell in *Canella alba*, in each cell of the upper epidermis in *Cinnamodendron macranthum*, and in small epidermal cells in *Cinnamosma fragrans*. In *Canella obtusifolia* and *Cinnamodendron macranthum* the stomata are only present on the lower side of the leaf, and are accompanied by subsidiary cells placed parallel to the pore. In all three genera the vascular bundles of the veins are strengthened both above and below by groups of fibres. In *Cinnamodendron* also three vascular bundles pass into the leaf.

3. STRUCTURE OF THE AXIS. Regarding the structure of the cortex we may add that in *Canella obtusifolia, Cinnamodendron macranthum* and *Cinnamosma fragrans* also the cork develops in the subepidermal layer of cells. In *Canella* only are the U-shaped sclerosed cells present in the phelloderm; this tissue is not sclerosed in *Cinnamodendron macranthum*, and in *Cinnamosma fragrans* sclerosis is only local. In all three genera the pericycle includes bundles of fibres, which in some cases only develop at a later stage.

Literature: [Greenish, *Canella* bark, Pharm. Journ. and Transact., xxiv, 1893–4, pp. 793–7.]—Parmentier, in Giard, Bull. scient. de la France et de la Belgique, xxvii, 1895–6, pp. 315–18.—Biermann, Oelzellen, Diss., Bern, 1898, pp. 29, 30.—Van Tieghem, Canellacées, Journ. de bot., 1899, pp. 266–76.—[Courchet, *Cinnamosma*, Ann. Inst. Marseille, 1906.]

BIXINEAE (pp. 87–91).

1. To the REVIEW OF ANATOMICAL FEATURES we may make the following additions. In the four genera of the Cochlospermeae the structure of the bast is like that of the lime and shows the same character in the primary cortical medullary rays, i.e. they broaden outwards like a wedge; the development of cork besides being subepidermal may also be epidermal and (*Aphloia*) pericyclic; groups of small epidermal cells containing crystals are also found in *Camptostylus, Erythrospermum, Itoa, Rawsonia,* and *Scottellia*; mucilaginous epidermal cells in the leaf are also met with in the genera *Amoreuxia* and *Marquesia*; mucilage-cells (not mucilage-canals) occur according to Van Tieghem in *Sphaerosepalum*; simple unicellular clothing hairs provided with blunt protuberances are found in *Hoplestigma*; tufted hairs also in *Marquesia*; peltate hairs also in *Camptostylus* and *Cochlospermum*; glandular hairs, differing in structure from those of *Oncoba* and *Poggea,* in *Hoplestigma* and *Marquesia*;

wart-like emergences on the petiole in *Scolopia*; hypoderm in the leaf also in species of *Itoa* and *Scottellia*; spicular fibres in the mesophyll also in *Centroplacus paniculatus*, Gilg (where their lumina are often filled with silica) and *Erythrospermum amplexicaule*, DC.

2. STRUCTURE OF THE LEAF. The spicular fibres of *Centraplacus* and *Erythrospermum* mentioned above were observed by Brändlein and Citerne respectively. The sclerenchymatous fibres of *Centroplacus paniculatus* branch off from the sclerenchyma of the veins, and sometimes show ramification themselves; they are specially distinguished by the frequent presence of amorphous silica filling their wide lumina. Mucilaginous **epidermal cells** also occur in *Amoreuxia palmatifida*, Moç. et Sessé, *Marquesia macrura*, Gilg, *Neumannia deltoides*, Warb., *N. minima*, Warb. and *N. theaeformis*, Rich. (species of *Aphloia*). A hypoderm of one or several layers is found beneath the upper epidermis in *Erythrospermum amplexicaule*, DC., *E. amplifolium*, *E. coronarium*, *E. laxiflorum*, *E. phytolaccoides*, *E. pyrifolium*, *E. tetrasepalon*, *E. verticillatum*, Lam., *Itoa orientalis*, Hemsl. (locally), and *Scottellia macropus*, Gilg et Dinkl., while a single hypodermal layer is situated above the lower epidermis in *Erythrospermum amplexicaule* and *E. verticillatum* (Brändlein, Citerne and Van Tieghem). The small crystal-idioblasts in the epidermis are recorded by Citerne in *Erythrospermum* (with clustered crystals) and by Brändlein in *Camptostylus caudatus*, Gilg (with clustered and solitary crystals), *Itoa orientalis* (clust. cryst.), *Rawsonia Schlechteri*, Gilg (clust. cryst.), and *Scottellia macropus* (clust. and solit. cryst.). A stomatal apparatus of a distinctly Cruciferous type is found also in *Centroplacus* and *Rawsonia*, whilst the Rubiaceous type is clearly developed also in *Carrierea*, *Itoa* and *Trichostephanus*; in the remaining genera investigated by Brändlein only ordinary neighbouring cells are present. The **stomata** of *Sphaerosepalum alternifolium*, Bak. occur on both sides of the leaf, and are provided with subsidiary cells (Van Tieghem).

In *Bixa*, *Erythrospermum* and *Sphaerosepalum* the vascular bundles of the **veins** are accompanied by sclerenchymatous fibres, but this is not the case in *Amoreuxia* and *Cochlospermum*. One or three vascular bundles pass out into the leaf. In the genera *Bixa*, *Cochlospermum* (*Maximilianea*), *Amoreuxia* and *Sphaerosepalum* (which was formerly included among the Guttiferae) —all four members of the Cochlospermeae—the three bundles, which enter the **petiole**, sooner or later unite to form a ring, and in *Bixa* the latter encloses an arc of wood and bast with the xylem directed upwards. In *Bixa* the vascular system of the midrib is the same as that of the petiole (this is contrary to the earlier statement on p. 89). In the Flacourtieae, on the other hand, there is either one vascular bundle (*Dovyalis*, *Flacourtia*, *Ludia*, *Scolopia*, *Xylosma*, &c.), or three (*Azara*, *Idesia*, *Tisonia*, *Trimeria*, &c.) which unite to form an arc open on its upper side; in this tribe the vascular system nowhere forms a ring. In the genus *Aphloia* (*Neumannia*), which in its anatomy departs in some respects (see the development of the cork) from the Flacourtieae, three vascular bundles (one large and two small) pass out from the axis into the petiole. In the same way three vascular bundles also occur in *Erythrochiton*, but a modification is introduced inasmuch as the bundles in this genus ultimately become concentric in structure.

In connexion with the subject of oxalate of lime (p. 89) we may mention that Fabricius' recent statement as to the occurrence of **cystoliths** in a member of this Order (*Aphloia madagascariensis*) is incorrect. The plant examined by Fabricius does not belong to the Bixineae, but was a specimen of *Artocarpus integrifolia*, L.f. (Urticaceae).

The most important addition to the previous statements on internal **secretory organs** is as follows. In *Sphaerosepalum alternifolium*, Bak., Van

Tieghem only met with mucilage-cells in the primary cortex of the branch, in the parenchyma of the petiole, and in the mesophyll; this is not quite in agreement with Warburg's earlier observations on the occurrence of mucilage-canals.

The secretory cells are also present in *Amoreuxia palmatifida*, Moç. et Sessé and *A. unipora*, Van Tieghem. They are quite generally distributed in the outer portion of the primary cortex of the branch, in the parenchymatous ground-tissue of the petiole, and in the mesophyll. The mucilage-canals actually exhibit lysigenous development, and are also found in the petiole and in the larger veins of the leaf; in the primary cortex they occupy the inner portion. A central, medullary mucilage-canal has only been recorded in the axis of *Bixa Orellana* and *Amoreuxia unipora*.

To the section dealing with the **hairy covering** we may firstly add that simple unicellular clothing hairs have been met with in *Carrierea*, *Hoplestigma* (where they bear the protuberances mentioned above), *Itoa* and *Marquesia*; in the last of these genera the simple hairs are accompanied by tufted hairs (Brändlein). Peltate hairs are described by Van Tieghem in *Cochlospermum*, and by Brändlein in *Camptostylus* (in this genus they have a short stalk and thin-walled ray-cells). The glandular trichomes of *Hoplestigma Pierreanum*, Gilg, which were likewise observed by Brändlein, are uniseriate and in some cases of great length; they consist of a few basal cells with relatively thick walls, followed by several longer cells with thin walls, and a rounded terminal cell, which is not sharply marked off, and has thin walls. According to the same authority, the glandular hairs of *Marquesia macrura* have a short stalk and an obliquely inserted head, the latter being multicellular and having both horizontal and vertical division-walls. According to Areschoug, the wart-like emergences, mentioned above, found on the petiole in *Scolopia* and having the function of hydathodes, include an epithema and the termination of a vascular bundle.

3. Structure of the Axis. The structure of the **cortex** has recently been investigated in detail by Van Tieghem, more particularly in the genera of the Cochlospermeae, as well as in *Aphloia* (*Neumannia*) and *Erythrospermum*. In *Bixa*, *Amoreuxia*, *Cochlospermum*, *Sphaerosepalum* and *Erythrospermum* the pericycle contains isolated bundles of bast-fibres, whilst in the Flacourtieae, according to Van Tieghem, though not quite in accordance with the earlier statements of Harms (see p. 87), a composite and continuous ring of sclerenchyma is quite generally developed. A similar ring is found in the pericycle in the species of *Aphloia*, and according to Pitard also in *Xylosma nitidum* (where it includes cells with U-shaped thickening), and in a plant described as *Rumea coriacea* (= *Xylosma nitidum* ex syn.!) (with ordinary stone-cells). A distinct endodermis composed of relatively large cells witb Caspary's dots on the radial walls is present in *Aphloia* only. The bast has a characteristic structure in four genera of the Cochlospermeae, viz. *Bixa*, *Amoreuxia*, *Cochlospermum* and *Sphaerosepalum*. The groups of phloem are narrowed outwards in the form of a wedge, while the primary medullary rays become correspondingly broader in the same direction; moreover the groups of bast show the same characteristic stratification into hard and soft bast as is seen in the lime. A similar broadening of the medullary rays outwards, and a narrowing of the phloem-groups between the rays is also more or less marked in *Erythrospermum*, but no secondary hard bast is present. In *Aphloia* sclerosis of the bast only occurs in the older branches. Bast-fibres occurring singly or in groups are formed from the thin-walled tissue in the outer portion of the phloem, whilst the tissue of the primary medullary rays between the phloem-groups undergoes sclerosis as far as the boundary of the xylem. Consequently the newly-formed soft bast appears in a transverse section in the form of nests of tissue corre-

sponding to the individual vascular bundles. In the typical Flacourtieae, according to Van Tieghem, there is neither stratification of the bast into hard and soft bast, nor any wedge-like broadening of the primary cortical medullary rays outwards. The cork arises in the epidermis in *Bixa* and *Amoreuxia*, in the outer cell-layer of the primary cortex in *Cochlospermum*, *Sphaerosepalum* and *Erythrospermum*, but on the inner side of the pericyclic parenchyma in *Aphloia*. The cells of the cork are flat and have thin walls in *Bixa*: they are flat and somewhat thickened in *Erythrospermum*, flat and provided with slightly thickened tangential walls in *Aphloia*, and so on.

Literature: Citerne, Berbéridées et Erythrospermées, Thèse, Paris, 1892, pp. 104 and 127.—Briquet, Hydathodes fol. des *Scolopia*, Bull. Herb. Boissier, 1898, pp. 503, 504.—Van Tieghem, Neumannié, Journ. de bot., 1899, pp. 361–7.—Van Tieghem, Bixacées, Cochlospermacées et Sphérosépalacées, Journ. de bot., 1900, pp. 32–54.—Van Tieghem, Érythrosperme, Journ. de bot., 1900, pp. 125–9.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 68.—Areschoug, Mangrovepfl., Bibl. bot., H. 56, 1902, pp. 61–3, and Tab. vi.—Fabricius, Laubblattanat., Beih. Bot. Centralbl., xii, 1902, pp. 317, 318.—Solereder, Zwei Bericht., Bull. Herbier Boissier, 1903, p. 318 et seq.—[Rippa, Nuovo genere etc. (*Licopolia*), Bull. Orto bot. Napoli, ii, 1904, p. 69 et seq.]—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl. 39, n. 2, 1905, pp. 103–5 (*Taraktogenos*), and pp. 116–18 (*Ryparosa*).—Brändlein, Syst.-anat. Untersuch. d. Bl. der Samydaceen, Benth.-Hook., Diss., Erlangen, 1906, Manuscript (*Camptostylus*, *Carrierea*, *Centroplacus*, *Hoplestigma*, *Itoa*, *Marquesia*, *Rawsonia*, *Scottellia*, *Trichostephanus*).—[For additional literature, see p. 1169.]

PITTOSPOREAE (pp. 91–94).

Literature: Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 40.—Hooper, Supposed *Beilschmiedea*-bark, Pharm. Journ., 1904, p. 361 et seq. (According to the results of my own investigation this bark belongs to *Pittosporum*.)—[For additional literature, see p. 1171.]

POLYGALEAE (pp. 96–100).

Regarding the anatomy of the saprophytic genus *Epirrhizanthes* we may note that the scale-leaves have no stomata, unicellular clothing hairs are present, and the vascular cylinder of the stem is enveloped by a ring of fibres.

Literature: Knoblauch, Oekolog. Anat. etc., Habilitat. Schr., Tübingen, 1896, p. 23 et seq.—Penzig, *Epirrhizanthes*, Ann. Jard. Buitenzorg, xvii, 1901, pp. 142–70, and Tab. xx–xxvi.—[For additional literature, see. p. 1171.]

VOCHYSIACEAE (pp. 100–104).

3. Structure of the Axis. Leisering thinks it probable that the interxylary phloem, which is also found in *Erisma nitidum*, DC., is developed by subsequent differentiation of sieve-tubes from parenchyma given off internally by the cambium.

Literature: Johannson, Noch wenig bek. Rinden, Diss., Dorpat, 1891, pp. 15–17.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 45, 46.

CARYOPHYLLEAE (pp. 107–111).

1. The Review of Anatomical Features requires the following additional remarks. The structure of the stomatal apparatus is not the same in all the members of the Order, the Caryophylleous type with two cells placed transversely to the pore being rare (*Loeflingia*) in the representatives of the tribe Polycarpeae. Solitary crystals of oxalate of lime probably only occur in exceptional cases (axis of *Polycarpaea filifolia*, Webb). Clothing hairs of a type not previously mentioned are branched sympodial trichomes with a varying number of rays (species of *Cerastium*, *Polycarpaea*, *Polycarpon* and *Stipulicida*).

The occurrence of secondary zones of growth has also been recently demonstrated in the axis of numerous species of *Polycarpaea*, as well as in the root of certain species of *Cerdia*, *Ortegia*, *Polycarpon*, *Pycnophyllum*, *Spergula*, *Spergularia* and *Stipulicida*.

2. Structure of the Leaf. A not uncommon feature in the Polycarpeae (*Loeflingia*, *Ortegia*, *Polycarpaea*, *Polycarpon*) is the presence of longitudinal rows of **epidermal cells** with vesicular papillose protuberances; they occur on the midribs and in the neighbourhood of the margin of the leaf. Similar longitudinal rows of papillae are found on the epidermis of the stem in species of *Loeflingia*, *Ortegia*, *Polycarpon* and *Stipulicida* (Jösting). Amongst the representatives of the Caryophylleae (especially the members of the Polycarpeae) investigated by Jösting, **stomata** of the Caryophylleous type are only present in *Spergularia* and *Loeflingia*, but not in *Spergula* nor in numerous other Polycarpeae examined in addition to *Loeflingia* (see also Lüders, loc. cit.). *Colobanthus kerguelensis*, Hook. f. has a one-layered hypoderm above the lower epidermis (Mardner). On the occurrence of water-pores, see Spanjer, loc. cit.

Neither unicellular clothing **hairs**, nor even unicellular trichomes of any kind occur in this Order. Jösting's statement as to their occurrence in *Polycarpaea* is certainly incorrect in the case of *P. Teneriffae*, Lam., and probably also *P. candida*, Webb et Berth. The branched multicellular hairs are more or less distinctly sympodial in structure; they have the form of a candelabra or stellate hair (*Cerastium mollissimum*, Poir., *Polycarpon Loeflingiae*, Benth. et Hook.), or one with two or more arms (*Cerastium dicrotrichum*, Fenzl, and species of *Polycarpaea*, including *P. Teneriffae*). Trichomes similar to those found in *Polycarpaea* appear to be present also in *Stipulicida*, according to Lüders. The uniseriate glandular hairs with a unicellular bead are also found in *Loeflingia*, *Spergula* and *Spergularia* (on the inflorescence).

3. Structure of the Axis. The structure of the stem has recently been investigated in the Sileneae and Alsineae, chiefly by W. Meyer, and in the Polycarpeae, especially by Jösting. The statements of the earlier authors have in some cases been confirmed by these researches, in other cases extended. With reference to the structure and position of the mechanical ring and its occasional absence, see the papers cited.

The development of **cork** in *Polycarpaea* also takes place immediately on the inner side of the pericyclic strengthening ring.

In the following additional cases **anomalous zones of growth** have been observed: by me, in the axis of *Polycarpaea aristata*, Chr. Sm., *P. carnosa*, Chr. Sm., *P. filiformis*, Webb, *P. latifolia*, Poir., *P. microphylla*, Cav., and *P. Smithii*, Link; by Jösting, in the root of *Ortegia hispanica*, L., *Polycarpaea Teneriffae*, Lam., *Polycarpon peploides*, DC., *Spergula arvensis*, L., *S. Morisonii*, Boreau and *Spergularia rubra*, Presl; by Lüders, in the root of unnamed species of *Cerdia*, *Pycnophyllum* and *Stipulicida*.

The development of the secondary zones is probably [1] in all cases extra-fascicular.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 80 et seq.—[Damanti, Nettarii estranuz. della *Silene fuscata*, Giorn. Soc. d'acclimaz. et agr. in Sicilia, 1885, p. 101; according to Just, 1885, i, p. 745.]—Börgesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl. 1897, iii, pp. 472–4.—Guffroy, *Dianthus*, Bull. Soc. bot. de France, 1898, p. 343.—Spanjer, Wasserapparate, Bot. Zeit., 1898, p. 53.—[Clements, Histog. of the Caryophyllales, I, Transact. Amer. Microscop. Soc., xx, 1899, pp. 67–164 and pl. viii–xxv; see also Contribs. from the bot. Lab., Univ. of Nebraska.]—W. Meyer, Vergl. Anat. d. Caryophyll. u. Primulaceen, Diss., Göttingen, 1899, 74 pp.—W. Meyer, Einfluss etc., Bot. Centralbl. 1899, iii, p. 337 et seq.—Kearny, in Contribs. U.S. Nat. Herb., v, 5, 1900, p. 302.—Thomas, Feuilles sout., Thèse, Paris, 1900.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 49.—Bouygues,

[1] Concerning *Spergularia* see also Jösting, loc. cit., pp. 166 and 180.

Pétiole, Thèse, Paris, 1902, p. 18.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902 (*Silene*).—Jösting, Anat. der Sperguleen etc., Beih. bot. Centralbl., xii, 1902, pp. 139-80 and Tab. iii-iv.—Mardner, Phan.-Veg. d. Kerguelen, Diss., Basel, 1902 (*Colobanthus*).—Amar, Oxalate de calcium, etc., Compt. rend. Paris, cxxxvi, 1903, pp. 901, 902.—[Armari, Piante della reg. medit., Ann. di bot., i, 1903, p. 17 et seq. (*Dianthus*).]—Theorin, Växttrichom., Arkiv för Bot., i, 1903, p. 172; see also loc. cit., iii, n. 5, 1904, p. 9, and iv, n. 18, 1905, p. 6.—Freidenfeldt, Anat. Bau der Wurz., Bibl. bot., H. 61, 1904, pp. 38-45.—Solereder, *Polycarpaea filiformis*, Bull. Herbier Boissier, 1904, p. 435 et seq.—Süssenguth, Behaarungsverh. der Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 22.—Sarton, Anat. d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 107-9 (*Saponaria*).—Weberbauer, Veget. d. Hochanden Perus, in Engler, bot. Jahrb., xxxvii, 1905, p. 60 et seq.—Dauphiné, Rhizomes, Ann. sc. nat., sér. 9, t. iii, 1906, p. 355 et seq.—Lüders, Syst. Untersuch. über die Caryophyll. mit einfachem Diagramm, Diss., Erlangen, 1907, pp. 33-38.—[Maheu et Combes, Format. subéro-phellod. anorm., Bull. Soc. bot. de France, 1907, p. 430 et seq. (*Gypsophila*).]

PORTULACEAE (pp. 111-113).

The genus *Lenzia* (with *L. chamaepitys*, Phil.) is placed amongst the *Genera incertae sedis* in Durand's Index, and is given as a doubtful member of the Amarantaceae in Engler and Prantl, but is considered by Reiche to belong to the Portulaceae. In this genus the structure of the axis is normal. The transverse section shows a number of isolated vascular bundles arranged in a ring, and a continuous pericyclic ring of mechanical tissue. The leaves are hard, and are provided with a membranous margin. On the lower side they have a hypoderm composed of thickened but not lignified cells elongated in the same direction as the leaf; on either side of the leaf this hypoderm projects beyond the assimilatory tissue, which consists of rounded cells, and thus constitutes the membranous margin of the leaf. The assimilatory tissue is traversed by a median vascular bundle. Numerous stomata are found on the upper side of the leaf.

With reference to the hairy covering we may mention Reiche's statements regarding *Calandrinia*. The papillae on the multiseriate shaggy hairs are in some cases rather strongly developed, so that 'pili plumosi' result, and occasionally a papillose branch terminates in a glandular head.

Literature: Reiche, *Calandrinia*, Ber. deutsch. bot. Gesellsch., 1897, p. 493 et seq.—Gasparis, Tessuto assimil. del genere *Portulaca*, Rendiconti Accad. Sc. fis. e mat. Napoli, 1901, pp. 201, 202.—[Holm, *Claytonia*, Mem. Nat. Acad. of Sc., Washington, x, 1905, pp. 27-37; abstr. in Bot. Centralbl. 101, p. 5.]—Reiche, Syst. Stellung von *Lenzia*, in Engler bot. Jahrb., xxxvi, 1905, pp. 84, 85.—[Holtermann, Einfluss d. Klimas, 1907, p. 87.]

TAMARISCINEAE (pp. 113-116).

2. Structure of the Leaf. In the first place we may add that in the species of *Tamarix* and *Myricaria* which have been investigated, the stomata are restricted to the upper side of the leaf (Vesque and Köhne).

Regarding *Fouquiera* the following statements may be added. The structure of the leaf varies from bifacial to centric. The stomata have no subsidiary cells. Oxalate of lime is present, and is deposited in the form of solitary crystals in the cortex, and of structures resembling sphaerites in the midrib of the leaf. Unicellular clothing hairs have likewise been observed. The conversion of the persistent part of the leaf into a thorn is due to the presence of a zone of sclerenchymatous fibres; in the basal portion of the petiole this zone occupies the whole of the space between the lower epidermis and the fibrovascular system, whilst higher up in the petiole it gradually narrows down so as merely to form a subepidermal group of cells separated by parenchymatous ground-tissue from the vascular system, as seen in transverse section; finally, the fibrous zone terminates in a point, which is either located in the petiole or most frequently in the lower or middle part of the

midrib of the leaf. At the end of the vegetative period the remaining parts of the petiole and lamina become detached from this mass of sclerenchymatous fibres, which then constitutes the foliar thorn found in the species of *Fouquiera*. The fibrous zone may be regarded as a continuation of the layer of sclerenchymatous fibres found in the primary cortex (see below).

3. STRUCTURE OF THE BRANCH. In the first place we may notice the characteristic structure of the outer zone of the primary **cortex**, common to all the species of *Fouquiera*. This zone originates by secondary division of the subepidermal layer of cells and consists either entirely, or only at certain points corresponding to the leaves situated immediately above, of a tissue composed of elongated sclerosed elements with narrow lumina and varying in the extent of its development according to the species. In older axes cork-formation sets in on the inner side of this sclerenchymatous zone, the cork consisting of cells with thin walls and wide lumina. The pericycle contains isolated groups of bast-fibres only in certain species of *Fouquiera* (*F. spinosa*, Torr. and *F. columnaris*, Kell.). According to Van Tieghem, secondary hard bast is not developed in *Fouquiera*. It still remains doubtful whether the 'horn-leaves' (Hornblätter) found in older stems of *Fouquiera splendens*, Engelm, and investigated in detail by Schaer, are really part of the secondary cortex, as this author assumes, or belong to the sclerenchymatous tissue above mentioned. These structures contain what is known as Ocotilla-wax, and are composed of peculiar fibrous cells, glued to one another by a substance resembling wax; similar substances are also present in the thick cellulose-walls. For details as to the nature of the pericycle in *Tamarix africana* and *Myricaria germanica*, see Pitard, loc. cit.; in these two species the pericycle, even in branches of slight thickness, includes a composite and continuous sclerenchymatous ring, which subsequently gets split open.

Literature: Poisson, Épines de l'*Idria columnaris*, Bull. Mus. d'hist. nat., i, 1895, pp. 278, 279. —Schaer, *Fouquiera splendens*, Archiv d. Pharm., 236, 1898, pp. 1-8.—Köhne, Papillen, Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 51.—Van Tieghem, Fouquieriacées, Journ. de bot., 1899, pp. 293-301.—Petersen, Vedanatomi, 1901, pp. 42, 43 (*Myricaria*).—Pitard, Péricycle. Thèse, Bordeaux, 1901, pp. 73, 74.—Jönsson, Anat. Bau d. Wüstenpfl., Lunds Univers. Årsskrift, xxxviii, 1902, p. 39.—[Robinson, Spines of *Fouquiera*, Bull. Torrey Bot. Club, xxxi, 1904, pp. 45-50.]—Piccioli, Legnami, Bull. Siena, 1906, p. 129.—[Holtermann, Einfluss d. Klimas, 1907, p. 92 (*Tamarix*).]

HYPERICINEAE (pp. 117–120).

1. ANATOMICAL FEATURES. In *Endodesmia* the cork develops in a sub-epidermal position, so that superficial cork-formation also occurs in this Order. The stellate hairs are accompanied by simple unicellular or uniseriate trichomes with thin walls and wide lumina. Papillose differentiation of the epidermis of the leaf has recently been observed in species of *Cratoxylon*, *Endodesmia*, *Haronga*, and *Hypericum*. Hypoderm has been recorded in the leaf in species of *Haronga*, *Hypericum* and *Psorospermum*. Interxylary phloem has been met with in the wood of *Endodesmia calophylloides*, Benth.

2. STRUCTURE OF THE LEAF. Nearly all the species of Hypericineae investigated by Kexel and Weill [1] have bifacial leaf-structure, the palisade-tissue in most cases consisting of a single layer of cells. Certain species of *Hypericum* (*H. Coris*, L., *H. ericoides*, L., *H. procumbens*) have rolled leaves. In *Hypericum ericoides* the upper epidermal cells bear papillae which are solid. Papillose differentiation of the lower **epidermis** is found in *H. procumbens* (only in the furrows), *H. Roeperianum*, Schimp., *Haronga madagascariensis*, Choisy, *Cra-*

[1] Weill's investigations extend to all the genera.

toxylon polyanthum, Korth., and I have myself found it also in *Endodesmia calophylloides*. In *Hypericum Richerii*, Vill., on the other hand, only isolated epidermal cells on both sides of the leaf are produced into papillae. I find the papillae present in *Haronga madagascariensis* to be particularly characteristic; they are long, finger-shaped, and rather thick-walled structures, which are frequently divided by transverse walls and are sometimes fused with one another. Hypoderm is present on the upper side of the leaf in *Haronga madagascariensis*, *Hypericum nanum*, *Vismia dealbata*, H. B., *V. ferruginea*, H. B., *V. guianensis*, DC., *V. parviflora*, Cham. and *V. viridiflora*, Duch.; on the lower side of the leaf in *Hypericum nanum* and *Psorospermum febrifugum*, Spach. Weill comes to the conclusion that the stomatal types found in the Hypericeae on the one hand, and in the Cratoxyleae and Vismieae on the other, do not present so uniform a character as Vesque maintains. Weill's investigations do not however appear to me to be quite reliable from this point of view, since in *Endodesmia calophylloides*, *Haronga madagascariensis* and *Vismia ferruginea* I was able to demonstrate the occurrence of the Rubiaceous type, which is contrary to Weill's statements. In exceptional cases (*Hypericum hyssopifolium*, L.) stomata also occur in small numbers on the upper side of the leaf.

In his description of the **secretory cavities**, which are filled with brown contents, Weill again disputes their schizogenous origin, and states that they arise from a group of secretory cells, in which the separating walls can ultimately no longer be demonstrated.

The **hairy covering** invariably consists of clothing hairs with thin walls. The hairs found in the species of *Hypericum* are unicellular or uniseriate, and in the latter case consist of from two to many cells, which vary in length and shape—sometimes even in the same trichome. I have examined the stellate or tufted hairs found in *Vismia* (also *V. ferruginea*, H. B.) and *Haronga*; they have numerous short ray-cells with thin walls and wide lumina, the rays being inserted at different levels. Weill's statement as to the occurrence of stellate hairs with a star-shaped terminal cell in *Vismia lauriformis*, Choisy, *V. ferruginea*, H. B. and *Psorospermum febrifugum*, Spach, as well as the corresponding figures, are incorrect as far as *V. ferruginea* is concerned, and the remaining cases require reinvestigation. In *Psorospermum senegalense*, Spach[1], the same author records only simpler uniseriate hairs with cells of unequal length.

3. STRUCTURE OF THE AXIS. The **wood** of *Endodesmia calophylloides* contains exceptionally numerous islands of soft bast, the innermost being found in the immediate neighbourbood of the pith, which has a four-rayed outline in transverse section; I am able to confirm this statement on the basis of an investigation of material of this species collected by Zenker. The outer (normal) soft bast is reduced in this case. The mode of origin of the interxylary phloem yet remains to be determined. The wood of *Endodesmia* exhibits the following structural features: (*a*) the medullary rays are narrow; (*b*) the vessels are isolated and some of them are of large size, the lumina invariably being rounded; they have simple perforations, and the walls bear relatively large simple pits as well as bordered pits in contact with parenchyma of the medullary rays; (*c*) the wood-prosenchyma is covered with small, but distinct bordered pits.

The pericycle in *Vismia* also contains a ring or isolated groups of **bast-fibres**. According to my own investigation *Endodesmia* possesses a composite and

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[1] I did not observe any capitate hairs ('poils capités à la face inférieure') in *Endodesmia*, although I met with papillose protrusion of the lower epidermal cells (see above).

continuous ring of sclerenchyma in the pericycle. In *Cratoxylon polyanthum*, according to Stepowski, a zone of bast-fibres is situated immediately beneath the epidermis of the stem, and on the inner side of this zone there is a layer of stone-cells, the inner tangential walls of which are thickened. The first cork in *Endodesmia* is developed in the subepidermal layer of cells and not in the pericycle, as was previously stated; in *Psorospermum febrifugum*, on the other hand, it arises in the pericyclic parenchyma. The cells of the cork in *Endodesmia* exhibit a U-shaped thickening, involving the outer tangential and the radial walls. In *Psorospermum febrifugum* the cork consists of alternating layers of unsuberized cells and of uniformly sclerosed cells, which, however, have fairly wide lumina; the former are elongated in the radial direction, and are occasionally subdivided by a tangential wall. The periderm in the root of *Hypericum Przewalskii*, Maxim. shows a similar structure. Prior to this J. E. Weiss had already described the occurrence of unsuberized cells (phelloid cells) in species of *Hypericum*.

For the distribution of the secretory organs, which Weill classifies as 'canaux' (in the pericycle and bast, sometimes also in the pith), 'poches fusiformes' (in the primary cortex, rarely in the pith), and 'poches sphériques ou ovoïdes' (in the mesophyll), and for the branching of the medullary secretory canals, see Weill's paper cited below.

Literature: Jodin, Org. sécrét., Thèse, Montpellier, 1888, p. 65 et seq.—J. E. Weiss, Korkbild. Denkschr. bot. Gesellsch. Regensburg, vi, 1890, p. 21.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Kexel, Anat. d. Laubbl. u. Stengel d. Hyperic. u. Cratoxyleae etc., Diss., Erlangen, 1896, pp. 1–36 and Tab.—Meehan, Pellucid dots, Proceed. Acad. Philadelphia, 1897, ii, pp. 181–3.—Petersen, Vedanatomi, 1901, p. 45 (*Hypericum*).—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 335 (*Cratoxylon*).—[Holm, *Triadenum virginicum*, Americ. Journ. Sc., 1903, p. 369 et seq.]—Weill, Rech. hist. sur la fam. d. Hyperic., Thèse, Paris, 1903, 189 pp.—Weill, Répart. d. app. sécrét. dans l'*Hypericum calycinum*, Journ. de bot., 1903, pp. 56–62.—Süssenguth, Behaarungsverh. der Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 23.—Sarton, Anat. d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 97, 98 (*Hypericum*).—Stepowski, Veg. Org. d. Burseraceae etc., Diss., Bern, 1905, pp. 106–9 (*Cratoxylon*).—[Moll and Janssonius, Mikrographie d. Holzes, Heft 1, Leiden, 1906, pp. 239–49 (*Cratoxylon*).]

GUTTIFERAE (pp. 120–126).

3. Structure of the Axis. In *Mesua ferrea*, L. the primary cortex contains a ring of stone-cells, which is only separated from the epidermis by a single layer of cells (Stepowski). The pericycle in *Mammea americana* and *Rheedia laterifolia* contains a composite and continuous ring of sclerenchyma, which includes U-shaped stone-cells (Pitard). In *Calophyllum Inophyllum*, L. the bordered pits on the vessels have a sieve-like structure (Ursprung), whilst connecting bands of wood-parenchyma are found also in *Symphonia gabonensis*, Pierre and *Pentadesma butyracea*, Don (Lecomte). The fruiting axes of *Tovomita guianensis* show polystelic structure.

Literature: Leblois, Thylles d. can. sécrét., Bull. Soc. bot. de France, 1887, p. 186.—Jadin, Org. sécrét., Thèse, Montpellier, 1888, p. 56 et seq.—Jönsson, Anat. Bau d. Bl., Acta Univ. Lund, xxxii, 2, 1896.—Ursprung, Anat. u. Jahresbild. trop. Holzarten, Diss., Basel, 1900, pp. 8–10 (*Calophyllum Inophyllum*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 66.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 336 et seq. (*Calophyllum*, *Garcinia*).—Pitard, Polystélie, Act. Soc. Linn. de Paris, sér. 6, t. vii, 1902, p. lxviii.—[Lecomte, Quelques bois du Congo, Bull. Mus. d'hist. nat., 1903, p. 89; according to Bot. Centralbl., xcii, p. 407.]—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 18–21, Tab. i, ii, viii, ix (*Garcinia*).—Stepowski, Veg. Org. d. Burseraceae, Dipterocarpeae u. Guttiferae, Diss., Bern, 1905, pp. 97–122[1].—[*For additional literature, see p. 1170.*]

[1] The *Cratoxylon polyanthum*, mentioned by Stepowski in this paper, diverges from the remaining Guttiferae in its anatomical structure, and is a member of the Hypericineae. The three-layered epidermis mentioned by the same author as occurring in the stem of *Clusia Criuva*, Camb. is probably of the nature of cork.

TERNSTROEMIACEAE (pp. 127–136).

1. The following ANATOMICAL FEATURES have been newly recorded:— uniseriate, multicellular clothing hairs and glandular hairs in the genus *Actinidia*; tufted hairs with unicellular rays in *Gordonia Lasianthus* and *Lacathea pubescens*; and the occurrence of oxalate of lime in the epidermis of the leaf in species of *Ternstroemia*. To the list of genera possessing sclerenchymatous idioblasts in the mesophyll the following should be added: *Camellia* (incl. *Thea*) and *Eurya*, which were omitted by mistake, and are considered under the structure of the leaf; further, the genera *Lacathea*, *Nabiasodendron*, and *Ruyschia*, and, if I understand Pitard rightly, also *Adinandra*, *Pyrenaria* and *Tremanthera*.

2. STRUCTURE OF THE LEAF. The anatomy of the leaf in the species of *Thea* has recently been investigated by Kochs[1]. According to him the characteristic features of the genus are the bifacial structure of the leaf, the absolute restriction of the stomata with their 3–4 narrow neighbouring cells to the lower leaf-surface, and the sclerenchymatous idioblasts found in the mesophyll. For the purposes of specific distinction the varying size, shape and contents of the epidermal cells are more particularly made use of.

The occurrence of sclerenchymatous **idioblasts** in the mesophyll has recently been recorded by A. Richter, Francken, Paoli, Pitard and myself in the following additional species: *Camellia Sasanqua*, Thunb., *Lacathea pubescens* (here extending from one epidermis to the other), *Marcgravia rectiflora*, Tr. et Pl.[2], *M. Sintenisii*, Urb. and *M. umbellata*, L. (asterosclereids), *Nabiasodendron* ('sclérites noduleux'), *Ruyschia clusiaefolia*, Jacq. (asterosclereids), *Ternstroemia Toquian*, Vill. (internal hairs); regarding the species of *Thea*, see also Kochs, loc. cit.

The diverse anatomical structure presented by the dimorphic leaves of the Marcgravieae has been reinvestigated by A. Richter and Paoli with reference to Juel's work. According to A. Richter, the most essential features of the leaves on the orthotropic shoots of *Marcgravia umbellata* as compared with those on the plagiotropic shoots are the presence of hypoderm on the upper side of the leaf and of numerous branched idioblasts in the spongy tissue, the smaller number of stomata on the upper and the larger number on the lower side, the different structure of the **guard cells**, the somewhat stronger development of the palisade tissue, and the smaller, though more numerous chloroplasts in the palisade parenchyma. Paoli describes the following characters as distinctive of the leaves on the fertile shoots as compared with those on the sterile shoots: relatively small epidermal cells on both sides of the leaf, a hypoderm on the upper side, a palisade of elongated cells, and numerous sclerenchymatous idioblasts in the spongy tissue.

In the genus *Stachyurus*, which systematists in recent times have regarded as constituting a separate Order (Stachyuraceae), **oxalate of lime** is excreted in the form of clustered crystals (in the primary cortex and medullary rays of the bast of the branch) (Van Tieghem). I have myself noticed small cells filled with clustered crystals and placed singly or in pairs in the lower epidermis of the leaf in *Ternstroemia Toquian*, Vill.; these cells often give the appearance

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[1] Unfortunately Kochs' statements are not sufficiently explicit. To ensure proper comprehension of his meaning, it is necessary to reinvestigate the material he examined. Thus he speaks of 'epidermal cells lying partly side by side and partly one above the other' (= a locally two-layered epidermis), or of 'isolated, relatively large cells, probably containing air (!) and frequently penetrating slightly into the tissue of the leaf' (perhaps mucilaginous epidermal cells), and so on.

[2] The small septate tubes which are described and figured by A. Richter in the mesophyll of this species, and which branch like the threads of a mycelium, are almost doubtless mycelial filaments; they are not mentioned by Paoli.

of the clustered crystals being merely embedded in the common wall of contact between the crystal-idioblasts and the adjoining epidermal cells. In another undetermined species of *Ternstroemia*, collected by Loher, I found solitary crystals in certain of the upper epidermal cells, which scarcely differed from the others. According to Dunac, styloids occur also in *Actinidia* (*A. chinensis*).

In amplification of the previous statements about the **hairy covering** we may first notice that, according to Dunac, the genus *Actinidia* possesses the following types of hairs in addition to unicellular clothing hairs: uniseriate trichomes; shaggy hairs (*A. Kolomicta*, *A. polygama*, *A. rufa*, *A. strigosa*, *A. tetramera*); stellate hairs (*A. Championi* and *A. chinensis*); and also short glandular hairs (*A. Kolomicta*). The tufted hairs mentioned by Pitard (treatise II) as occurring in *Gordonia Lasianthus* and *Lacathea pubescens* are, according to my own investigation, of the first of these species, composed of 2–4 ray-cells, arranged like a fan.

According to Kochs, most species of *Thea* exhibit a tendency to form cork-warts on the lower surface of the leaf. Extra-floral nectaries are found, for example, in *Marcgravia rectiflora*, where they occur in scattered arrangement on the lower side of the leaf, being 15 in number and ·5–1 mm. in diameter; in *M. umbellata*, on the other hand, they are present to the number of four or five at the base of the leaf (Paoli). In the latter species they constitute small pit-like depressions, the epidermis of which is differentiated as an epithelium.

Detailed statements as to the structure of the **petiole** are made by Pitard (II), although his observations only extend to members of the Tribes Gordonieae and Ternstroemieae, or in other words to Pitard's two groups, Ternstroemiées and Théées [1]. In these groups the base of the petiole usually contains a single vascular bundle, which is often very much reduced, and in transverse section has the shape of a U or a widely open semilunar form. Inrolling of the margins of the furrow formed by the vascular bundle only occurs in *Freziera*. In a few cases (*F. reticulata*) the vascular system is divided into three bundles. According to Van Tieghem, three vascular bundles enter the leaf in *Stachyurus*, these bundles being distinct from one another in their course through the petiole.

3. Structure of the Axis. In all the members of the Order investigated by Pitard the **wood** contains isolated vessels with narrow lumina and numerous very delicate medullary rays.

In Pitard's sub-tribes Ternstroemieae, Adinandreae and Schimeae, the development of the **cork** takes place in the subepidermal layer of cells, whilst in the Haemocharideae and Camellieae the cork arises in the pericycle. In *Stachyurus* [2], according to Van Tieghem, the phellogen appears in the epidermis. In the Camellieae the primary cortex is cast off at an early stage as a result of cork-development, whilst in the Haemocharideae it remains on the branch for a long time.

In the Ternstroemieae sens. str. and Schimeae, as well as in the Theeae, the **primary cortex** contains abundantly branched sclerenchymatous idioblasts with long and pointed arms; in the Adinandreae, on the other hand, the

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[1] For the sake of brevity at this point and in my subsequent synopsis of Pitard's (ii) investigations on the structure of the axis, I here append the system of classification established by him, in which anatomical characters are taken into consideration: I, Ternstroemieae: 1, Ternstroemieae sens. strict.: *Ternstroemia*, *Anneslea*; 2, Adinandreae: *Adinandra*, *Visnea*, *Cleyera*, *Eurya*, *Freziera*, *Tremanthera*; 3, Schimeae: *Schima*, *Lacathea*, *Gordonia*. II, Theeae: 1, Haemocharideae: *Nabiasodendron*, *Haemocharis*, *Pyrenaria*; 2, Camellieae: *Camellia*, *Thea*, *Stewartia*.

[2] In the root of *Stachyurus* the development of the cork takes place in the pericycle.

idioblasts in the primary cortex have a more rounded shape, and only exhibit short and blunt branches. In all the species investigated by Pitard (II), the pericycle of branches, which have attained a thickness of 5 mm., is composed of sclerosed cells as well as of unlignified cells with thin walls. In the Adinandreae a composite and continuous ring of sclerenchyma is subsequently developed; if I understand Pitard (in treatise I) rightly, a similar ring appears in the species there enumerated by him and belonging to *Caraipa*, *Eurya*, *Haploclathra*, *Kielmeyera*, *Mahurea*, *Marcgravia*, *Marila*, *Norantea*, *Pentaphylax*, *Ruyschia*, *Schima*, and *Saurauja* pro parte, whilst isolated groups of bast-fibres are stated to occur in species of *Anthodiscus*, *Caryocar*, *Saurauja* (pro parte) and *Ternstroemia*. In *Caraipa*, *Haploclathra*, *Kielmeyera* and *Marila*, according to Pitard (I), the sclerenchyma-ring includes stone-cells exhibiting U-shaped thickening.

In the Ternstroemieae sens. str. and Haemocharideae the secondary bast contains short fibrous sclerites, provided with short branches ('sclérites fibriformes noduleux'), while in the Adinandreae and Schimeae there are numerous long bast-fibres, which are only wanting in *Eurya*.

The **pith** is stated by Pitard to be in general homogeneous, while in the Camellieae it is very heterogeneous.

It remains to mention the polystelic differentiation of the vascular system in the fruit-stalks of *Schima Noronhae* (Pitard), in which the normal ring of vascular bundles is surrounded by rather numerous small steles.

Strasburgeria.

This genus, which will best be discussed at this point, is included amongst the Ternstroemiaceae in Durand's Index, being referred to the Tribe Gordonieae; in the supplement to the Natürl. Pflanzenfamilien it is appended to the Ochnaceae with a query; and recently it has been regarded as the type of a separate Order (Strasburgeriaceae) by Van Tieghem. Anatomically its most noteworthy features are the presence of mucilage-cells in the ground-tissue and the occurrence of cortical vascular bundles.

Regarding the structure of the **branch**, or rather of the cortex, the following statements may be made. The mucilage-cells lie singly or in groups in the outer portion of the primary cortex, and are also distinguished from the surrounding cells by their larger lumina. The cork develops in the subepidermal layer of cells. The pericycle at first contains small isolated bundles of bast-fibres, but subsequently a composite and continuous ring of sclerenchyma is formed. The secondary bast includes neither bast-fibres nor stone-cells. Crystals of oxalate of lime occur in the pith, but there are no mucilage-cells.

The **petiole** contains three isolated vascular bundles and a number of smaller bundles as well. Mucilage-cells are found in the petiolar parenchyma.

The lamina of the **leaf** presents the following structural features. The epidermis consists of large cells. Certain of the upper epidermal cells contain sphaerocrystalline masses of unknown chemical composition (not oxalate of lime). Beneath the upper epidermis there is a one-layered hypoderm, the mucilaginous cells of which penetrate into the single layer of palisade-tissue. The stomata are found only on the lower side of the leaf, and are not accompanied by any special subsidiary cells. The structure of the leaf is bifacial. The spongy tissue contains mucilage-cells.

Literature: Pierre, Flore forest. de la Cochinchine, ix, 1888 (*Archytaea*).—Keller, Luftwurzeln, Diss., Heidelberg, 1889, pp. 18–22.—Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 40–5.—[Cavara, Idioblasti delle Camellie, Atti R. Istit. bot. Pavia, ser. 2, vol. iv, 1895, p. 27; according to Bot. Centralbl. Beih., v, p. 422.]—Tschirch-Oesterle, *Atlas*, *1895*, *p. 9 and Tab. iii.*—Dunac, *Actinidia*, Compt. rend., Paris, cxxviii, 1899, pp. 1598-1601.—A. Richter, Adatok a Marcgraviaceae etc., Természetrajzi Füzetek, 1899, pp. 27–87, and Tab. ii–v.—Van Tieghem, Actinidie et Sauravie, Ann. sc. nat., sér. 8, t. x, 1899, pp. 137–40; also in Journ. de bot., 1899, pp. 170–3.—Kochs, *Thea*, in Engler, bot. Jahrb., xxvii, 1900, p. 606 et seq. (also Diss., Erlangen, 63 pp., especially p. 34 et seq.).—Van Tieghem, Stachyuracées etc., Journ. de bot., 1900, pp. 1–6.—Pitard (i), Péricycle, Thèse, Bordeaux, 1901, pp. 60–2 and 90.—Bargagli-Petrucci, Legnami,

Malpighia, 1902, p. 334 (*Archytaea*).—Bouygues, Pétiole, Thèse, Paris, 1902, p. 16.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 27, 28 (*Visnea*).—Pitard (ii), Polystélie, Act. Soc. Linn. Bordeaux, sér. 6, t. vii, 1902, C. R., p. lxviii; Rapp. et classificat. des Ternstroemiac., loc. cit., p. l et seq.; *Nabiasodendron*, loc. cit., p. lv; *Visnea* etc., loc. cit., p. lxix; and Caract. anat. gén. des Ternstroemiac., loc. cit., pp. lxxi–lxxiv.—Poulsen, Bladkirtl. hos *Marcgravia umbellata*, Vidensk. Meddelelа. Kjøbenhavn, 1902, pp. 244–6.—Van Tieghem, Strasburgérie, Journ. de bot., 1903, pp. 199, 200.—Paoli, Eterofillia, Nuov. Giorn. bot. Ital., xi, 1904, pp. 210–16, and Tab. ii.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 31, 32 (*Thea*).—Piccioli, Legnami, Bull. Siena, 1906, p. 149.—[For additional literature, see p. 1172.]

DIPTEROCARPEAE (pp. 136–145).

1. Anatomical Features. Extrafloral nectaries occur in *Shorea*. Large crystal-idioblasts, the inner walls of which are mucilaginous or merely thickened, are found in the mesophyll in certain species of *Doona* and *Hopea*. Silica-bodies are present in the parenchymatous tissues of the wood (according to Bargagli-Petrucci) in species of *Dryobalanops* and *Cotylelobium*.

2. Structure of the Leaf. Epidermal cells showing palisade-like elongation, stomata with two subsidiary cells placed parallel to the pore, and glandular hairs with a multicellular peltate head are found also in *Vateria Seychellarum* (Fabricius). Guérin records gelatinization of cells of the upper epidermis in further species of *Dipterocarpus*, and also in certain species of *Balanocarpus*, *Doona*, *Hopea* and *Shorea*. The crystal-idioblasts observed by the same author in the mesophyll of *Doona nervosa*, Thw., *D. zeylanica*, Thw., and *Hopea cernua*, Teijsm. et Binn., deserve special mention; these elements, which are situated immediately below the upper epidermis, have mucilaginous inner membranes and contain a solitary crystal. Similar crystal-cells are found also in other species of *Hopea* (*H. dryobalanoides*, Miq., *H. jucunda*, Thw., *H. Mengarawan*, Miq., *H. nigra*, Burck, *H. Pierrei*, Hance), but in these cases the thickened inner walls do not swell up in water (‘ mucilage fortement condensé,’ according to Guérin); the cells, moreover, are commonly placed several side by side and occur also next to the lower epidermis. Finally, according to Guérin, in certain species of *Balanocarpus*, *Dipterocarpus*, *Doona*, *Hopea* and *Shorea*, the ground-tissue of the petiole, and in some cases also that of the midrib and lateral veins, contains cells with mucilaginous membranes or whole rows of such cells (cf. under structure of the axis).

The extrafloral nectaries situated on the lower side of the stipules and on the upper side of the foliage leaves in *Shorea stenoptera*, Burck, are disc-shaped structures, consisting of two layers of cells derived from the epidermis, viz. of an upper secretory layer composed of long prismatic cells and of a lower layer of suberized cells, which are quadratic in section. The domatia found in many members of the Order, such as species of *Balanocarpus*, *Doona*, *Hopea*, *Isoptera*, *Pentacme* and *Shorea*, must not be confused with the extrafloral nectaries; these domatia appear on the under side of the leaves along the midribs and in the axils of the lateral veins of the first order (see Guérin, loc. cit.).

3. Structure of the Axis. Guérin has recently investigated the distribution of the mucilaginous cells in the axis in certain species of *Balanocarpus*, *Dipterocarpus*, *Doona* and *Shorea*. They are found chiefly in the primary cortex, more rarely also in the pith. In *Doona* Guérin only met with a small quantity of mucilage in the primary cortex; this is contrary to Brandis's statements.

The course of development of the interxylary resin-canals has formed the subject of investigations undertaken by Guérin on *Dipterocarpus*. According to this authority the origin is schizogenous, the canals arising between four cells of the cambium. In this respect, as well as in the occurrence of occasional

anastomoses, these resin-canals resemble those of the genera *Copaifera* and *Daniella* (Caesalpinieae). Interxylary resin-canals have been recorded by Guérin and Bargagli-Petrucci also in species of *Anisoptera*, *Balanocarpus*, *Cotylelobium*, *Doona*, *Tsoptera*, *Monoporandra*, *Pachynocarpus*, *Pentacme* and *Vateria*.

Stepowski's statement (loc. cit., p. 92 and Fig. 47) as to the occurrence of resin-canals with a small lumen in the secondary cortex of *Vateria indica*, L. remains to be explained; for, to judge by the structure of the leaf, which is described in the same paper, the material on which the investigation was undertaken would appear to have been correctly determined.

APPENDIX: 1. *Ancistrocladus* (pp. 143, 144).

Van Tieghem's recent investigations, in which he splits up *Ancistrocladus* into three genera, *Bigamea*, *Ancistrocladus* and *Ancistrella*, necessitate the addition of the following statements.

All parts of the primary cortex of the **branch** contain relatively large secretory cells, filled with hyaline contents and provided with lignified membranes; these secretory elements may occur either isolated or in groups. In *Ancistrella Barteri*, V. T. the primary cortex also includes a few isolated fibrous cells. The development of the cork takes place on the inner side of the endodermis, viz. in the outermost layer of pericyclic cells. The pericycle is at first parenchymatous, but subsequently comes to contain a number of sclerenchymatous elements, which in some cases unite to form an almost continuous ring; occasionally these elements appear in two forms, viz. as short cells with a tendency to stellate differentiation and as fibrous cells.

In *Ancistrocladus* and *Bigamea* the **leaf** exhibits more or less distinct palisade tissue on its upper side, and veins which are vertically transcurrent by means of sclerenchyma, whilst in *Ancistrella Barteri* there is a one-layered hypoderm on the upper side with a subjacent palisade layer. The peltate glands previously described by me constitute a feature characteristic of all the Ancistrocladeae; these glands are sunk in depressions on the surface of the leaf, and excrete wax. The stomata are invariably situated on the lower side of the leaf, and are not provided with special subsidiary cells. According to Van Tieghem, a special character of the fibrovascular system of the midrib is found in the occurrence of a pericyclic zone of fibres in the peripheral portion of which, in the lower part of the curve, 5–19 small vascular bundles with inverse orientation of wood and bast are embedded. These bundles can be traced to a varying distance along the midrib, and are only absent in *Bigamea hamata*, V. T.

Three vascular bundles enter the leaf and at once unite to form a tube, which in *Ancistrocladus* can be traced along the whole length of the midrib. In *Bigamea* the tube opens out and assumes the form of an inverted omega (℧); in addition to that, a vascular bundle is found at each of the two margins of the fibrovascular arc, these bundles having their bast directed upwards and their xylem pointing downwards. In *Ancistrella* the tube remains closed, the vascular system on the upper side of the curve exhibiting inverse orientation (bast below and wood above, as in the lower portion of the curve).

2. *Lophira* (p. 144)

The following additional details regarding the structure of the **branch** are based on Van Tieghem's statements. The primary cortex includes branched stone-cells containing crystals, as well as clustered and solitary crystals. The number of cortical vascular bnndles is 24 or more. The pericyclic groups of hard bast subsequently unite to form a composite and continuous ring of sclerenchyma, which at a still later stage again becomes split open. The development of cork takes place in the subepidermal layer of cells. The bundles of medullary fibres are accompanied by chambered crystal-fibres containing solitary crystals.

According to Van Tieghem's recent investigations, the earlier statement (by Heim) regarding the occurrence of subsidiary cells to the stomata is incorrect.

The large number (as many as 16) of radial vascular bundles, participating in

the formation of the fibrovascular system of the root, deserves mention; it is exceptionally large for a Dicotyledonous plant.

3. *Monotes* (p. 144).

As a result of renewed investigation Gilg again includes this genus amongst the Dipterocarpeae, though in the absence of resin-canals it certainly occupies an anomalous position amongst the members of this Order. According to Gilg, however, it is noteworthy that Welwitsch describes *Monotes* as 'frutex resinosus,' so that the question arises whether excretion of resin may not take place in older parts of the stem.

Literature: Leblois, Thylles de can. sécrét., Bull. Soc. bot. France, 1887, p. 187.—Jadin, Org. sécrét., Thèse, Montpellier, 1888, p. 54 et seq.—Pierre, Flore forest. de la Cochinchine, xv, 1890; xvi, 1891; and xvii, 1892.—Brandis, in Sitz.-Ber. Niederrhein. Gesellsch. Bonn, 1896, pp. 6–8.—Poulsen, Nektarier, Vidensk. Meddelelser, Kjøbenhavn, 1897, pp. 368–70.—Gilg, *Monotes*, in Engler Bot. Jahrb., xxviii, 1899, p. 127 et seq.—Figdor, Anat. d. Stammes der Dammarpfl., Österreich. bot. Zeitschr., 1900, p. 74 et seq.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 40 and 104.—Van Tieghem, *Lophira*, Journ. de bot., 1901, pp. 169–94, especially pp. 171–9.—Bargagli-Petrucci, Concrezioni silicee, Malpighia, 1902, p. 23 et seq.; and Legnami, loc. cit., p. 338 et seq. (*Balanocarpus*, *Dipterocarpus*, *Dryobalanops*, *Hopea*, *Shorea*, *Vateria*).—Fabricius, Laubblattanat., Beih. bot. Centralbl., xii, 1902, pp. 308–10.—Van Tieghem, Ancistrocladées, Journ. de bot., 1903, pp. 151–68, especially pp. 155–65.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 123, 124 and Tab. xvii.—Guérin, Appareil sécrét. d. Dipterocarp., Compt. rend. Paris, cxl, 1905, pp. 520–2; and Canaux sécrét. du bois d. Diptérocarp., loc. cit., cxlii, 1906, pp. 102–4.—Stepowski, Veg.-Org. d. Burseraceae, Dipterocarpeae, etc., Diss., Bern, 1905, pp. 53–95.—Guérin, Domaties des feuilles des Dipterocarp., Bull. Soc. bot. France, 1906, pp. 186–92; and Cellules à mucilage des Diptérocarp., loc. cit., 1906, pp. 443–51.—[For additional literature, see p. 1170.]

CHLAENACEAE (pp. 145, 146).

The pericycle of the **axis** contains isolated bundles of bast-fibres also in *Schizolaena elongata* and *Scleroolaena Richardi*; in *Sarcolaena eriophora* and *Rhodolaena Humblotii* sclerosed parenchyma occurs at some points between the groups of primary bast-fibres (Pitard [1]).

MALVACEAE (pp. 146–152).

2. Structure of the Leaf. Nestler states that the glandular **hairs** of the Malvaceae can also function as hydathodes, that short multicellular glandular trichomes occur in species of *Abutilon*, *Althaea*, *Hibiscus*, *Kitaibelia*, *Lavatera*, *Malope*, *Malva*, *Palava*, *Plagianthus* and *Sidalcea*, while hairs with a long stalk and a unicellular head are recorded in *Abutilon* and *Kitaibelia vitifolia*, Willd.

According to Terraciano, extrafloral **nectaries** occur also in species of *Adansonia*, *Chorisia*, *Ceiba* and *Pachira*, being situated on the lower side of the midrib of the leaf and on the dorsal surface of the petioles. The nectaries on the midrib show a low type of differentiation and vary in position, number, and shape. The petiolar nectaries constitute one or more longitudinal furrows or small elliptical pits; in the former case they are sometimes provided with special excretory surfaces.

These nectaries, like those of *Hibiscus*, &c., which were mentioned in the earlier part of this work, all possess a tissue in which the nectar is formed, and numerous multicellular external glands serving the purpose of secretion [2].

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[1] Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 102, 103.

[2] The nectaries on the calyx, on the other hand, have a secretory palisade-epidermis.

3. Structure of the Axis. Bargagli-Petrucci has recently investigated the distribution of the peculiar structural features exhibited by the medullary rays of the xylem in the Bombaceae, which I was the first to observe. He describes the occurrence of special tiers in the medullary rays in further species of *Boschia*, *Durio* and *Neesia*, as well as in *Coelostegia borneensis*, Becc., and *Cullenia excelsa*, Wight, both of which likewise belong to the sub-tribe Durioneae. On the other hand no tiers are developed in the Adansonieae (species of *Adansonia*, *Bombax*, *Ceiba*, *Chorisia*) and Matisieae (species of *Cavanillesia*, *Montezuma*, *Ochroma*, *Quararibea*), or in *Camptostemon aruense*, Becc. and *Dialycarpa* (*Brownlowia*) *Beccarii*, Mast.

According to Bargagli-Petrucci, silica-bodies are found in the wood-parenchyma in *Coelostegia borneensis*, Becc.

We may also notice at this point that the vascular system in the fruit-stalks of *Adansonia digitata* shows polystelic structure.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 109 et seq.—Barber, Corky excresc., Ann. of Bot., vi, 1892, p. 163.—Gerber, *Adansonia*, Thèse, Paris, 1895, pp. 33–51, pl. i–ii.—[Mirabella, Colleteri, Contribuz. Ist. bot. Palermo, ii, 1897, p. 15 et seq.; abstr. in Just, 1897, i, p. 513.]—Nestler, Wassertropfen an den Bl. d. Malvac., Sitz.-Ber. Wiener Akad., cvi, 1, 1897, pp. 387–96, with Tab.—[Zancla, Aculei, Contribuz. Ist. bot. Palermo, ii, 1897, p. 1 et seq.]—Nestler, Schleimzellen d. Laubbl. d. Malvac., Österreich. bot. Zeitschr., 1898, pp. 94–9 and Tab. vi.—Terraciano, Nett. estranuz. nelle Bombacee, Contribuz. Ist. bot. Palermo, ii, 1898, pp. 137–91, tab. xv–xviii.—Nestler, Sekrettropf., Sitz.-Ber. deutsch. bot. Gesellsch., 1899, p. 332 et seq.—Kearny, in Contribut. U. St. Nat. Herb., v, 1900, p. 303 (*Kosteletzkya*).—Pitard, Polystélie, Act. Soc. Linn. de Bordeaux, sér. 6, t. v, 1901, pp. lxi, lxii; and Péricycle, Thèse, Bordeaux, 1901, p. 40.—Bargagli-Petrucci, Concrez. silicee, Malpighia, 1902, p. 23 et seq.; and Legnami, loc. cit., 1902, p. 327 et seq.—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 13.—Theorin, Växttrichom., Arkiv för Bot., i, 1903, p. 160; and iv, n. 18, 1905, p. 20.—Bargagli-Petrucci, Oss. anat.-sist. sulle Bombacee, Nuovo Giorn. bot. Ital., xi, 1904, pp. 407–15.—Chrysler, Strand-plants, Bot. Gazette, xxxvii, 1904, p. 461 et seq. (*Hibiscus*).—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 108–11.—Ursprung, Dickenwachst., Bot. Zeit., 1904, p. 202 (*Eriodendron*).—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 56–8 (*Dicellostyles*), pp. 64–6 (*Thespesia*).—Weberbauer, Veget. der Hochanden Perus, in Engler Bot. Jahrb., xxxvii, 1905, p. 60 et seq.—[For additional literature, see p. 1171.]

TRIPLOCHITONACEAE.

Triplochiton scleroxylon, K. Schum. (Zenker, No. 298, Kamerun, Herb. Berol.)[1] was examined. In the structure of its bast and the possession of intercellular secretory receptacles, some of which contain mucilage, *Triplochiton* shows affinity to the remaining Malvales. The stomata are surrounded by ordinary epidermal cells. Oxalate of lime is excreted in the form of clustered and solitary crystals. No trichomes were observed.

Structure of the **leaf**. The epidermal cells are polygonal in surface-view and none of them are mucilaginous. Stomata are found only in the lower epidermis. The mesophyll is composed of palisade tissue, the upper layers of which are typically differentiated, while the lower ones consist of conjugate elongated cells. The vertical transcurrence of the smaller veins is especially characteristic; their vascular bundles are surrounded by a layer of fibrous cells, which is prolonged on the upper side into a narrow plate of fibres extending as far as the epidermis, whilst on the lower side, between the bundle-sheath and the lower epidermis, there is mostly a secretory cavity enveloped by special conjunctive tissue. Relatively large clustered crystals are met with in the fibrous plates belonging to the veins, and smaller ones are found in the bast of the larger veins; solitary crystals are rare. Secretory cavities are situated also in the large lateral veins, where they occupy the

[1] The second genus of the Order (*Mansonia*, Prain, indigenous in Burma) was not available.

same position as in the smaller veins; they are present in the bast as well. Their contents, as far as they could be determined, are certainly in some cases mucilaginous, whilst in others they are of a different nature.

The transverse section of the **branch** shows (empty) secretory spaces in the inner portion of the primary cortex and in the pith. The phloem is stratified into hard and soft bast. The cortex contains clustered crystals, rarely solitary crystals. The wood is soft and consists principally of: (*a*) vessels with rather wide lumina, simple perforations and bordered pits in contact with parenchyma of the medullary rays; (*b*) relatively broad medullary rays, attaining a width of four cells; and (*c*) wood-fibres bearing simple pits.

STERCULIACEAE (pp. 152–155).

1. Anatomical Characters. Extrafloral nectaries occur in *Pterospermum javanicum*, Jungh. Silica-bodies are found in the wood-parenchyma in species of *Heritiera* and *Sterculia*. The vascular system in the fruit-stalks of *Helicteres jamaicensis*, *Kleinhovia Hospita* and *Sterculia platanifolia* is polystelic.

2 and 3. Structure of the Leaf and Axis. The tufted and stellate **hairs**, which are widely distributed in the Sterculiaceae, generally have unicellular rays; in *Dombeya* (*Astrapaea*) *Wallichii*, Benth. and Hook., however, I have found the rays to be occasionally uniseriate with several thin transverse walls.

The extrafloral nectaries, found in *Pterospermum javanicum*, although not present in other species of *Pterospermum* growing in Java, are constituted by one of the two stipules of the foliage-leaf. This stipule is hollowed out so as to be goblet-shaped, and is clothed with abundant stellate hairs; the cavity contains numerous pearl-glands in the form of relatively large glandular bodies composed of numerous cells and provided with a short stalk (Raciborski).

Doussot publishes a few statements on the structure of the **petiole**. According to him the fibrovascular system of the petiole in most cases (species of *Sterculia, Heritiera, Pterospermum, Kleinhovia, Lasiopetalum, Theobroma, Abroma, Hermannia, Cheiranthodendron*) consists of a ring of wood and bast, or of a ring of vascular bundles; in *Cola acuminata* there are two arcs of wood and bast with the xylem portions turned towards one another, while in *C. Ballayi* there is a single arc of the same kind. In addition to these main systems, the pith in some of the species of *Sterculia* contains one or more normally orientated vascular bundles, in *Heritiera* a second ring of wood and bast, and in *Cola acuminata* one or two smaller bundles.

In amplification of the previous discussion of the **mucilage-receptacles** we may in the first place notice that, according to Doussot, the mucilage-canals of *Sterculia acerifolia*, *S. platanifolia*, *Cola acuminata*, and '*Pterospermum saigonense*' are partly lysigenous and partly schizogenous in origin, while the mucilage-receptacles (canals and cavities) of '*Abroma orbicularis*' are invariably lysigenous. The development of the mucilage-receptacles in the individual genera therefore requires further detailed investigation. According to the same authority it is noteworthy that the number of mucilage-canals may vary at different levels in one and the same plant, and that at some points the canals may be replaced by mucilage-cavities.

To the review given on p. 153 of the detailed distribution of the mucilage-canals in the axis, the following additions may be made on the basis of Doussot's and Ledig's statements. Mucilage-canals are found in the following additional species:—(1) in the **pith** and **primary cortex**: *Sterculia acerifolia*, *S. foetida*,

S. '*furcata,*' *S.* '*monophylla,*' and *S. tomentosa*[1]; *Cola Ballayi* and *C. gabonensis*; *Helicteres involucrata*; *Pterospermum* '*saigonense*'; *Ruizia variabilis*; *Astrapaea Wallichii.* (2) in the pith, but not in the cortex: *Heritiera littoralis*; *Kleinhovia Hospita* (but with numerous mucilage-cavities in the primary cortex); *Pterospermum suberifolium* (many mucilage-cavities in the primary cortex); *Abroma orbicularis.*

Before leaving this subject we may notice the occurrence of interxylary mucilage-canals in the older portions of the axis in *Brachychiton populneum* and *Theobroma Cacao* (Mangin).

According to Van Tieghem, the (lysigenous) mucilage-cavities and mucilage-cells are absent in *Hermannia, Mahernia, Rulingia, Büttneria, Lasiopetalum, Thomasia* and *Melochia,* and according to Doussot also in *Heritiera littoralis* (in contradistinction to *H. macrophylla*). Doussot, on the other hand, states that mucilage-cells occur in the pith of *Hermannia candicans,* and mucilage-cells and cavities in the pith of *Lasiopetalum ferrugineum.* These facts show that it is necessary to investigate the mucilage-receptacles of the Sterculiaceae in each individual species before they can be employed for generic diagnosis and classification within the Order. Schizogenous mucilage-cavities, situated in the pith of the branches and petioles, are stated to be characteristic of *Ayenia* and *Commersonia.* Doussot records the occurrence of mucilaginous epidermal cells in species of *Sterculia, Brachychiton, Cola, Theobroma, Abroma, Hermannia* and *Dombeya.*

A brief account of the mucilage-receptacles found in the root may be added on the basis of Doussot's results. Amongst the investigated Sterculieae the roots of all except *Heritiera* (*Sterculia, Brachychiton, Cola*) contain only mucilage-cavities and mucilage-cells. The mucilage-cavities are confined to that part of the main root which is situated immediately next to the 'collet'; they may be present in the primary cortex, in the medullary rays of the bast, and in the wood (here in the wood-parenchyma or in the medullary rays). They have been observed in the wood in *Sterculia Balanghas, S. foetida, S.* '*monophylla,*' *S. platanifolia, Brachychiton acerifolium* and *B. populneum.* In '*Abroma orbicularis*' mucilage-cavities only are found in the medullary rays of the bast, while in *Hermannia candicans* the primary cortex and bast contain mucilage-cells alone. In *Heritiera, Pterospermum, Theobroma Cacao, Dombeya spectabilis* and *Cheiranthodendron platanifolium* there are no mucilage-receptacles whatsoever.

Literature: Ledig, Gummikanäle, Bot. Centralbl., 1881, ii, pp. 387–9.—Jadin, Org. sécret., Thèse, Montpellier, 1888, p. 61 et seq.—Johannson, Rinden, Diss., Dorpat, 1891, pp. 8–11.—Mangin, Gomme chez les Stercul., Compt. rend. Paris, cxxv, 1897, pp. 725–8.—Börgesen og Paulsen, Veget. dansk.-vestind. Öer, Bot. Tidsskrift, xxii, 1898–9, p. 93 (*Melochia tomentosa*).—[Hartwich, Ersatz der Quillajarinde, Schweizer. Wochenschr. f. Chemie, 1899, n. 49; abstr. in Just, 1899, ii, p. 28; cortex and wood of *Sterculia cordifolia*, Cav. contain saponin!]—Raciborski, Myrmekophile Pfl., Flora, 1900, p. 38 et seq.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 106–8.—Bargagli-Petrucci, Concrez. silicee, Malpighia, 1902, p. 23 et seq.; and Legnami, loc. cit., p. 331 et seq. (*Heritiera, Sterculia*).—Doussot, Appareil gommifère des Stercul., Thèse, Paris, 1902, 75 pp.—Pitard, Polystélie, Act. Soc. Linn. Bordeaux, sér. 6, t. vii, 1902.—Barteletti, Corteccia di *Pterospermum platanifolium*, Nuov. Giorn. bot. Ital., x, 1903, p. 566.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 123.—Ursprung, Dickenwachstum, Bot. Zeit., 1904, p. 205 (*Melochia*).—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, p. 63 (*Büttneria*), p. 96 (*Dombeya*), pp. 79, 80 (*Büttneria*), pp. 118–20 (*Pterospermum*).—Haberlandt, Lichtsinnesorg., 1905, p. 96.—[Prain, Mansonieae, Journ. Linn. Soc., xxxvii, 1905, p. 250 et seq.]

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[1] The 'septate latiferous tubes' recorded by Ledig in *Sterculia Balanghas* are merely lysigenous mucilage-canals.

TILIACEAE (pp. 155–159).

3. STRUCTURE OF THE AXIS. A composite and continuous ring of sclerenchyma in the pericycle is present also in the genus *Sloanea* (Pitard). Silica-bodies have been observed in the wood-parenchyma in *Brownlowia* sp. (P. B., no. 3652) (Bargagli-Petrucci).

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 111 et seq. (*Elaeocarpus*).—Nanke, Dikotyle Holzpfl., Diss., Königsberg, 1886, p. 27 et seq.—Börgesen og Paulsen, Veget. dansk.-vestind. Öer, Bot. Tidsskrift, xxii, 1898–9, p. 94 (*Corchorus hirsutus*).—Paulesco, Struct. anat. des hybrides, Thèse, Genève, 1900, p. 69 (*Tilia*).—Petersen, Vedanatomi, 1901, p. 45 (*Tilia*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 70 and 108.—Bargagli-Petrucci, Concrez. silicee, Malpighia, 1902, p. 23 et seq.; and Legnami, loc. cit., p. 325 et seq. (*Berrya*, *Brownlowia*).—Bouygues, Pétiole, Thèse, Paris, 1902, p. 10.—Fritsch, *Plagiopteron fragrans*, Ann. of Bot., xvi, 1902, pp. 177–80.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 136.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 136–8 (*Grewia*).—[Frommel, Plantas text. Chil., 1905, p. 32.]—Haberlandt, Lichtsinnesorg., 1905, p. 97.—Piccioli, Legnami, Bull. Siena, 1906, p. 147.—[Holtermann, Einfluss d. Klimas, 1907, p. 118 (*Elaeocarpus*).]

RHAPTOPETALACEAE[1].

The following anatomical features are common to the different members of the Order: The bilateral structure of the branch, and in connexion with this the occurrence of two cortical vascular bundles; the superficial development of the cork; the presence of isolated groups of bast-fibres in the pericycle; the stratification of the phloem into hard and soft bast; narrow medullary rays and rather abundant development of wood-parenchyma; stomata with three subsidiary cells of different sizes. The only kind of trichomes found are unicellular clothing hairs. Oxalate of lime is deposited only in the form of solitary crystals. There are no mucilage-cells. On the other hand, spicular fibres have been observed in the mesophyll in species belonging to all four genera.

Structure of the **leaf**. The mesophyll is in most cases bifacial, although the palisade-tissue is not always distinctly developed. In certain species of *Scytopetalum* and *Oubanguia* the epidermal cells are elongated and divided by tangential walls; *Brazzeia* has large epidermal cells, the inner walls of which are convexly arched, while some of the cells are filled with red contents. Gelatinization of the epidermis has not been observed. The stomata are found either on both sides of the leaf or only on the lower side. In *Oubanguia* and *Rhaptopetalum* the three subsidiary cells of the stomata have violet or brown contents, while in *Brazzeia* such contents are found only in the smallest subsidiary cell; in *Scytopetalum* they are altogether wanting. The spicular fibres above mentioned as occurring in all four genera are connected with the sclerenchyma of the veins; they traverse the mesophyll and ultimately spread out beneath the epidermis. The fibres are not always present; for example, not in *Scytopetalum Pierreanum* (De Wild.), V. T. In *S. Pierreanum* the smaller veins of the leaf are vertically transcurrent, whilst in *Oubanguia* they are almost transcurrent.

An arc-shaped vascular bundle passes out into the leaf. The **petiole** contains three bundles, viz. a large median one and two smaller lateral strands.

Unicellular clothing **hairs** have been observed on the branches only in species of *Brazzeia* and *Rhaptopetalum*.

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[1] This Order (Scytopetalaceae of Engler), founded by Pierre on the genus *Rhaptopetalum* (which was formerly included among the Olacineae), and a few other genera, is related to the Malvales. According to Van Tieghem, it may be subdivided into the Oubanguieae with *Oubanguia* and *Scytopetalum*, and the Rhaptopetaleae with *Brazzeia* and *Rhaptopetalum*. The above description is based on Van Tieghem's paper cited below.

In dealing with the structure of the **wood**, Van Tieghem merely states that the medullary rays are from one to three cells in breadth, and that wood-parenchyma is developed in some quantity in all four genera. According to Engler, the wood in *Scytopetalum Klaineanum*, Pierre contains the following elements : (*a*) scalariform and reticulate vessels with wide lumina and very steep transverse walls exhibiting scalariform perforations ; (*b*) vessels with narrower lumina ; (*c*) tracheids ; and (*d*) libriform (i.e. wood-prosenchyma with simple pits). The **pith** is lignified.

In the structure of the **cortex** the following points may be mentioned. The development of cork in *Oubanguia* takes place in the subepidermal layer of cells, or locally in the second layer of the primary cortex, while in *Scytopetalum*, *Brazzeia* and *Rhaptopetalum* it commences in the epidermis. In *Rhaptopetalum* the cork includes cells with U-shaped thickening. The two genera of the Oubanguieae are characterized by the fact that all the different parts of the primary cortex (even the subepidermal layer and the endodermis) contain cells with U-shaped thickening and with or without an enclosed crystal of oxalate of lime (Van Tieghem's ' cristarque '-cells) ; in some cases (*Scytopetalum*) the cells are uniformly thickened all round. In the Rhaptopetaleae, on the other hand, cells of this type are wanting. For details as to the course of the two cortical vascular bundles, see Van Tieghem ; regarding the pericycle and bast, cf. above.

Literature: Engler, Scytopetalaceae, in Natürl. Pflanzenfam., Nachtr. z. ii.–iv. Teil, 1897, pp. 242, 243.—Van Tieghem, Rhaptopétalacées, Ann. sc. nat., sér. 9, t. i, 1905, pp. 321–88.

LINEAE (pp. 159–160).

1. The following characters, newly recorded in certain members of the Order, may be added to the Review of Anatomical Features : deposition of oxalate of lime in the form of clustered crystals ; epidermal cells in the leaf containing solitary crystals (*Erythroxylon Coca*) ; occurrence of peg-shaped cystolith-like bodies (*E. obtusum*) ; presence of hypoderm in the leaf ; sclerenchymatous idioblasts in the mesophyll (species of *Erythroxylon*) ; occurrence of cells exhibiting U-shaped thickening and containing solitary crystals, i.e. ' cristarque '-cells (species of *Erythroxylon* and *Aneulophus*) ; cortical vascular bundles (*Erythroxylon*). The development of the cork is superficial, taking place in the subepidermal layer in *Erythroxylon*, and in the epidermis in *Aneulophus*.

2. Structure of the Leaf. Wilde has recently investigated species of *Linum*, *Radiola* and *Reinwardtia*, whilst Hartwich has examined species of *Erythroxylon*, and Van Tieghem the genera *Erythroxylon* and *Aneulophus*. In certain species of *Linum* the leaf is centric in structure ; it is also approximately centric in *Erythroxylon tortuosum*, in which the cells constituting the lowest layer of the mesophyll have the same form as the spool-shaped girder-cells found in Papilionaceous seeds. According to Van Tieghem, gelatinized **epidermal cells** are found on the upper side of the leaf in all the species of *Erythroxylon* examined by him, as well as in *Aneulophus africanus*, Benth., *Hugonia montana*, Pierre, and *Roucheria Contestiana*, Pierre. A one-layered **hypoderm** is situated on the upper side of the leaf in *Ixonanthes cuneata*, Miq. According to my own observation certain of the lower epidermal cells in the leaf of *Erythroxylon Coca* contain solitary crystals of oxalate of lime, these cells being sometimes arranged in pairs. Papillose differentiation of the lower epidermis is of frequent occurrence in the genus *Erythroxylon*, e.g. in *E. ovatum* and *E. subrotundum* (Hartwich). The **stomata** are accompanied by subsidiary

cells placed parallel to the pore, also in *Aneulophus, Radiola* and *Reinwardtia*. In *Erythroxylon bolivianum*, Burck certain cells of the lacunar spongy tissue are sclerosed (Hartwich). According to Hartwich, typical sclerenchymatous **idioblasts**, usually assuming the shape of a T, are found in *Erythroxylon acutifolium, E. citrifolium, E. mucronatum* and *E. squamatum*; these elements traverse the palisade-tissue, and then continue their course between the latter and the epidermis. Van Tieghem also records 'sclérites rameuses' in *Erythroxylon amplum, E. campestre, E. lucidum*, and *E. suberosum*, whilst Pierre mentions 'rares spicules' in *Hugonia montana*, Pierre. According to Van Tieghem, the vascular bundles of the **veins** are provided with bundles of sclerenchymatous fibres in *Aneulophus* and *Erythroxylon*; in *Aneulophus* and some of the species of *Erythroxylon* these fibres are accompanied by 'cristarque'-cells.

The clustered **crystals** above mentioned have been observed in the primary cortex in *Reinwardtia indica*, Dum., and in the secondary bast in *Erythroxylon pulchrum* (Wilde and Johannson). The cystolith-like bodies appear as small unlignified peg-shaped structures, arising from the middle of the outer wall of the upper epidermal cells and occasionally showing stratification; they have only been met with in *Erythroxylon obtusum* (Hartwich).

In *Aneulophus, Erythroxylon, Hugonia, Ixonanthes* and *Roucheria*, as well as in the genus *Ctenolophon*, which has been transferred from the Olacineae to the Lineae by Pierre, three vascular bundles branch out from the axis into the leaf. Van Tieghem gives the following description of the **petiole** in *Aneulophus* and *Erythroxylon*. Of the three vascular bundles passing out into the leaf in *Erythroxylon*, the two lateral strands depart from the vascular ring of the axis in the lower portion of the internode; they consequently traverse the upper part of the internode as cortical bundles. These two bundles each give off a branch to the stipules, and finally on entering the petiole fuse with the median bundle, which leaves the axial vascular ring at the node, to form an arc of wood and bast. In *Aneulophus* the three vascular bundles unite to form a similar arc of wood and bast, but here the bundles only emerge at the node. In some of the species of *Erythroxylon* the ground-tissue of the petiole contains irregularly scattered 'cristarque'-cells, while in *Aneulophus* such cells are found in the subepidermal and endodermal layers.

3. Structure of the Axis. According to Wilde, the xylem contains vessels with simple perforations and libriform also in *Linum* and *Radiola*. In *Aneulophus* and *Erythroxylon* the cells of the cork have thin walls (Van Tieghem). Wilde records a distinct endodermis in *Reinwardtia indica*, and a pericycle including isolated groups of fibres in *Linum* and *Radiola linoides*, Gmel. According to Van Tieghem, isolated groups of bast-fibres are present in the pericycle also in the species of *Erythroxylon*, while in *Aneulophus* a composite and continuous ring of sclerenchyma is formed at an early stage. 'Cristarque'-cells are only found in the primary cortex in part of the species of *Erythroxylon*; in a few species (*E. anguifugum, E. suberosum*) they are situated in the second layer of cortical cells, but in most cases (*E. amplum, E. campestre, E. citrifolium, E. deciduum, E. lucidum, E. nitidum*, &c.) they are irregularly distributed throughout the whole thickness of the primary cortex. In the monotypic genus *Aneulophus* the 'cristarque'-cells are confined to the subepidermal layer and the endodermis (see above, under petiole). In *Erythroxylon Coca* cells with yellowish or yellowish-red contents are found in the primary cortex, as well as in the pith. The secondary bast of *E. tortuosum* includes groups of stone-cells, while that of *E. australe* and other species contains bundles of fibres; the latter are especially numerous in *E. suberosum*, where they cause a stratification of the bast (Van Tieghem). In *E. pulchrum* the secondary bast includes fibrous cells and stone-cells (Johannson); in

Aneulophus there is practically a second sclerenchymatous ring exhibiting the same structure as that found in the pericycle and having a layer of 'cristarque'-cells on its outer side (Van Tieghem).

Literature: Johannson, Noch wenig bekannte Rinden, Diss., Dorpat, 1891, p. 39 et seq. (*Erythroxylon*).—[Tognini, Fasci libro-legn. prim. negli org. veg. del lino. Atti Ist. bot. Pavia, 1891, 21 pp.; according to Bot. Centralbl., l, p. 337.]—Pierre, Flore forest. de la Cochinchine, xviii, 1893.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 16.—Wilde, Beitr. z. Anat. d. Lineae, Diss., Heidelberg, 1902, 56 pp. and 1 Tab.—Hartwich, Cocablätter, Archiv d. Pharm., 241, 1903, pp. 617–30. and Tab. i. ii.—Van Tieghem, Erythroxylacées, nouv. ex. de cristarque, Bull. Mus. d'hist. nat., 1903, pp. 287–93.—[Greenish, Structure of Coca leaves, Pharm. Journ., 1904, pp. 493–6.]—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 24.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 38, 39 (*Erythroxylon*).—Theorin, Växttrichom., Arkiv för Bot., iv, n. 18, 1905, p. 7.—[O. E. Schulz, Erythroxylaceae, in Pflanzenreich, Heft 29, 1907, pp. 4–6].—[Tammes, Flachsstengel, Natk. Verh. holland. Mij. Wet., 1907, 285 pp.]

HUMIRIACEAE (pp. 160, 161).

Colozza's[1] investigation of the structure of the **leaf** in the species of Humiriaceae contained in the Florence Herbarium has afforded the following additional facts. The leaves are invariably bifacial in structure. In *Humiria* and *Vantanea* the cells of the upper epidermis are larger than those of the lower, and are differentiated as aqueous tissue; in *Sacoglottis*, on the other hand, the epidermal cells on both sides of the leaf are small. In *Humiria* the cells of the palisade-tissue are much elongated, whilst in *Vantanea* and *Sacoglottis* they are not so long, or even scarcely elongated; the genus last named has 2–3 layers of palisade. In *Sacoglottis cuspidata*, Urb. and *S. guianensis*, Benth. em. the mesophyll contains numerous sclerenchymatous idioblasts which run from one epidermis to the other and have swollen or forked terminations. The median vein in all the members of the Order includes a stele with an enveloping ring of mechanical tissue. In certain species of *Sacoglottis* the leaves bear short, conical unicellular clothing hairs.

For details as to the structure of the **petiole**, the transverse section of which is circular in *Vantanea*, circular or semicircular in *Sacoglottis*, and triangular in *Humiria*, see Colozza, loc. cit.

According to Pitard[2], a composite and continuous ring of sclerenchyma in the pericycle of the **axis** is present also in *Aubrya gabonensis* and in additional species of *Humiria* and *Vantanea*.

MALPIGHIACEAE (pp. 161–167).

3. STRUCTURE OF THE AXIS. A composite and continuous ring of sclerenchyma is developed in the pericycle in *Heteropteris laurifolia* (Pitard). Pierre's statement (in Flore forest. de la Cochinchine, xvii, 1892; see also xviii, 1893) regarding the occurrence of 'poches à contenu blanc spécial' in the cortex of the branch of *Aspidopterys costulata*, Pierre, requires further investigation; the contents of the sacs are stated to be coloured blue by iodine.

Note. In Bibl. bot., Heft 56, 1902, p. 77 and Tab. vii–viii, Areschoug publishes the results of examination of leaves belonging to a plant originally referred to ***Derris uliginosa***, **Benth., but subsequently stated by the same authority (in Flora, 1903, p. 302) to belong to *Tristellateia australasiae*, A. Rich. (Malpighiaceae); since the leaves in question bear peculiar three-celled trichomes of a simple type, the material is certainly not referable to a member of the Malpighiaceae.**

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[1] Colozza, Note anat. sulle foglie delle Humiriac., Nuovo Giorn. bot. Ital., xi, 1904, pp. 235–45.
[2] Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 77, 78.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 113 et seq.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 40 and 67.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 25, 26.—Viret, Liaisons du phloème méd. etc., Inst. de Bot. Genève, 1904, pp. 46–63 (*Dicella*).—[For additional literature see p. 1171.]

ZYGOPHYLLEAE (pp. 167–169).

STRUCTURE OF THE LEAF. In *Nitraria Schoberi*, L. and *N. tridentata*, Desf., the mesophyll contains mucilage-cells like those found in *N. retusa*; tanniniferous idioblasts have, however, only been observed in *N. Schoberi* and *N. retusa* (Jönsson). We may add that according to the same author gelatinization occurs in the axis in *N. Schoberi* and leads to the formation of large mucilage-lacunae, situated in the primary and secondary cortex. These lacunae generally originate as intercellular spaces, and undergo subsequent enlargement at the expense of the cells of the surrounding tissue; after this process of resorption the contents of the lacunae in some cases include large numbers of crystals of oxalate of lime. In the species of *Fagonia*, *Guaiacum*, *Larrea*, *Porlieria*, *Tribulus* and *Zygophyllum*, investigated by Pantanelli, the stomata are small and are either sunk or raised above the level of the epidermis; they have no subsidiary cells. The cuticle of the epidermis varies very much in thickness. A specially noteworthy feature is the occurrence of spicular fibres in the mesophyll in *Nitraria Schoberi*; these fibres branch off from the sclerenchyma of the veins, and traverse the palisade-tissue on the upper side of the leaf, penetrating as far as the epidermis (Jönsson).

According to Pantanelli, the fibrovascular system of the **petiole** is constituted by: (*a*) a principal system composed of 3–4 (*Fagonia*) or 4–6 (*Tribulus*) vascular bundles or of a ring of bundles (*Zygophyllum*, *Porlieria*, *Guaiacum*, *Bulnesia*, *Larrea*); and (*b*) an auxiliary system consisting of two lateral vascular bundles, which are situated towards the upper side.

For the structure of the petiolar cushions of *Porlieria hygrometra* and *Guaiacum officinale*, L., see the papers by Paoletti, Pantanelli, and Rodrigue.

STRUCTURE OF THE AXIS. According to Pantanelli, the cork is in most cases (including *Zygophyllum album*, L.) developed in a subepidermal position, but in *Fagonia cretica*, L. it arises on the inner side of the pericyclic groups of bast-fibres; the latter feature has by the way been previously recorded by Vesque (in Ann. sc. nat., sér. 6, t. ii, p. 194). In *Bulnesia Retamo* the primary cortex contains stone-cells (Pantanelli), whilst in *Larrea nitida* there is a composite and continuous ring of sclerenchyma in the pericycle (Pitard). In *Fagonia*, *Tribulus* and *Zygophyllum* the pith is composed of a thin-walled tissue serving the purpose of water-storage; in *Porlieria* it is made up of coarsely punctate cells, while in *Guaiacum officinale* it includes stone-cells (Pantanelli). According to Pantanelli, a tier-like structure is exhibited by the xylem-mass also in *Larrea cuneifolia*, Cav.

The vascular system of the **root** is diarch (*Fagonia*, *Tribulus*, and *Zygophyllum*) or triarch (*Guaiacum*, *Porlieria*).

Literature: Paoletti, *Porlieria hygrometra*, Malpighia, iv, 1890, pp. 34–40, and Nuovo Giorn. bot. Ital., 1892, p. 65 et seq., especially pp. 68–71.—Wilson, Leaves and stipules of *Larrea mexicana*, Transact. and Proceed. Bot. Soc. Edinburgh, xix, 1893, pp. 185–90.—Gamper, Angosturarinden, Diss., Zürich, 1900, p. 60.—Pantanelli, Anat. fisiol. delle Zygophyll., Atti della Società dei natural. e matemat. di Modena, ser. iv, vol. ii, 1900, pp. 93–181, tav. viii–xi; and Pulvini motori etc., loc. cit., p. 201 et seq.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 76.—Jönsson, Anat. Bau d. Wüstenpfl., Lunds Univers. Årsskr., xxxviii, 1902, Afd. 2, n. 6, p. 22 et seq. and Tab. ii–iii.—Pätzold, Harz u. Holz von Guaiacum, Diss., Strassburg, 1902, 122 pp.—Rodrigue, *Porlieria hygrometra* [Arch. Sc. phys. et nat. Soc. helv., 1902, pp. 140–2; Actes Soc. helv. sc. nat., 1902, p. 72]; and Bull. de l'Herbier Boissier, ii, 1902, p. 893.—[Holtermann, Einfluss d. Klimas, 1907, p. 83 (*Tribulus*).]

GERANIACEAE (pp. 169–174).

1. The Review of Anatomical Features requires the following additions. The heads of the glandular hairs are for the most part unicellular, but in exceptional cases (species of *Oxalis*) they may be multicellular. Glandular shaggy hairs occur in *Biebersteinia*. In *Rhynchotheca* oxalate of lime is deposited in the form of styloids, which had hitherto not been recorded in this Order. Secretory cells are found side by side with the secretory cavities in species of *Oxalis*. The epidermis of the leaf in *Tropaeolum maius*, L. includes elongated cells with mucilaginous contents. Septate laticiferous tubes (?) are present in the tuberous roots of a few species of *Tropaeolum*. Hard hast is occasionally wanting in the pericycle.

2. The Structure of the Leaf in the Geraniaceae has recently been studied in detail as follows: by Brunies in *Biebersteinia, Monsonia, Sarcocaulon, Geranium, Erodium, Pelargonium, Viviania, Rhynchotheca, Wendtia, Balbisia* and *Dirachmia*; by Magnus in *Tropaeolum*; by Chauvel in the genera *Hypseocharis, Oxalis, Biophytum, Eichleria, Averrhoa, Connaropsis* and *Dapania*, which belong to the Oxalideae; and by Brunotte in *Impatiens*. In many species of *Oxalis*, e. g. *O. articulata*, Sav. or *O. montevidensis*, Prog. (on the upper side of the leaf) and *O. brasiliensis*, Lodd. (on both sides of the leaf), the **epidermis** consists of remarkably large cells and is differentiated as aqueous tissue. Hypoderm is found beneath the upper epidermis in *Dapania scandens*, Stapf. Papillose differentiation of the lower epidermis has recently been recorded also in *Eichleria Blanchetiana*, Prog., *Rhynchotheca spinosa*, R. et P. (poorly developed), *Oxalis articulata*, Sav., *O. corniculata*, L. var. *purpurea*, *O. halophylla*, Arech., *O. hirta*, L. and *O. Osteni*, Arech. In *Tropaeolum peregrinum*, L. chlorophyll is present in the epidermis. The **stomata** are placed at different levels. In *Averrhoa, Biophytum*, and *Eichleria*, according to Chauvel, there are two neighbouring cells, or at least one such cell, lying parallel to the pore. A study of the course of development of the stomata in *Tropaeolum* has shown that three neighbouring cells are formed before the mother-cell of the guard-cells becomes differentiated (Magnus). Water-pores functioning as hydathodes occur also in certain species of *Oxalis*, and are situated in the depressions of the emarginate leaflets. The neighbouring cells of the water-pores in *Oxalis* like those of *Tropaeolum* are occasionally (e. g. in *O. Schraderiana*, H. B. K.) papillose. The **mesophyll** is for the most part bifacial, although centric (homogeneous) structure, with uniform assimilatory tissue composed of rounded cells, is also met with. *Balbisia microphylla*, Phil. has rolled leaves, the stomata being contained in two furrows, situated one on either side of the principal vein on the lower side of the leaf. In *Pelargonium coronopifolium*, Jacq. the two halves of the leaf are revolute, so that a deep furrow is formed; the stomata in this species, however, occur in approximately equal numbers on both sides of the leaf. With reference to the **veins** we may mention that enlarged terminal tracheids are characteristic of *Averrhoa, Biophytum* and *Eichleria*. According to Irgang, the drops, which appear on pricking or cutting through the veins of the leaf, the petioles and relatively young stems of *Tropaeolum majus*, emanate from tubular cells situated in the xylem and provided with rather wide lumina, a nucleus and protoplasmic contents; these cells are merely the young segments of the vessels, which in this case persist in an unaltered condition for an exceptionally long time.

We may now pass on to consider the clothing **hairs**. Unicellular and uniseriate trichomes in some cases occur in the same species. According to Brunies, the Geraniaceae investigated by him have clothing hairs in which the basal portion has a characteristic structure; it is inserted between the

epidermal cells and is generally conical or shaped like a truncated cone, and only in rare cases has a cylindrical form. As specially noteworthy, we may mention the unicellular trichomes, which Fredrikson met with on the bulb-scales in certain species of *Oxalis*; the longitudinal wall of these hairs has an uneven surface due to small (*O. incarnata*, L., loc. cit., Tab. I, fig. 15) or spinose (*O.* sp. 349, loc. cit., Tab. II, fig. 25) papillae. At this point we may also refer to the short trichomes found in *Impatiens Mariannae*, Reichb.; in their typical form these hairs consist of a large basal cell and a plano-convex lens-shaped cell, but they occasionally exhibit transitions to longer uniseriate hairs or may be reduced to a single large epidermal cell, the outer wall of which is arched outwards in a spherical manner. These structures are regarded by Haberlandt as local organs for light-perception (ocellae). Glandular hairs having a stalk of varying length and a unicellular head are found also in the genera *Averrhoa*, *Biophytum*, *Monsonia*, *Viviania* and *Wendtia*. The following special types of glandular hairs have been newly recorded: unicellular clavate hairs (*Oxalis rhombifolia*, Jacq. according to Chauvel, and *O.* sp. 346 according to Fredrikson); glandular hairs with a very long stalk and a unicellular head (*O. refracta*, St. Hil. var. *typica* and *O. subcorymbosa*, Arech. according to Chauvel); hairs with a long stalk and an ellipsoidal head, subdivided into three cells by means of horizontal walls (*O. amara*, St. Hil. according to Chauvel); lastly, the glandular shaggy hairs of *Biebersteinia multifida*, DC., described by Brunies as emergences, which consist of a long multiseriate stalk and a knob-shaped head composed of numerous cells. Regarding the structure of the glandular appendages (extra-floral nectaries) occurring on the petiole and stem in the species of *Impatiens*, see also Aufrecht and Brunotte, loc. cit.

Oxalate of lime is also deposited in the form of styloids[1] (parenchyma of the veins of *Rhynchotheca spinosa*). Large idioblasts containing clustered crystals are found in the mesophyll in many species of *Erodium*, and in *Pelargonium anatymbicum*, Steud., while idioblasts with solitary crystals are met with in certain species of *Oxalis*. Other features of special note are: the sphaero-crystalline or clustered aggregates found in species of *Monsonia* and *Erodium*; the short, moniliform rows of cells filled with clustered crystals occurring in the veins of the leaf in species of *Wendtia*; and the rows of crystal-cells (with solitary crystals) accompanying the vascular bundles of the veins to which they form a kind of sheath in *Averrhoa*, *Biophytum* and *Eichleria*.

Chauvel, Fenizia and Fredrikson have published new data on the distribution of the **secretory cavities** in *Oxalis*; Fredrikson, however, only examined the bulb-scales. According to Chauvel, the secretory cavities are a constant feature in the acauline species, although they also occur in certain species which have a well-developed stem (e. g. *O. cernua*, Thunb. or *O. Deppei*, Lodd.). The secretory cavities found in the bulb-scales are situated on the dorsal side of the vascular bundles, and are often elongated so as to resemble canals. Those occurring in the foliage-leaves are chiefly marginal in position; more rarely they are distributed over the entire surface of the leaf (e. g. in *O. articulata*, Sav. and *O. hirta*, L.), while in other cases again (e. g. in *O. Deppei*) there is a single large secretory cavity at the end of the median vein. According to Chauvel, the mode of development of these glands is lysigenous and not schizogenous, as was formerly stated. Chauvel failed to observe a lining layer

[1] It may be pointed out here that Höhnel met with 'prismatic crystals of oxalate of lime, of exceptionally large size and rhombic in section' (presumably also styloids) in Churco bark, which is imported from Chili and is rich in tannin; this bark is stated by Höhnel and Wiesner to be derived from *Oxalis gigantea*, Barn., while according to the former authority its structure is quite identical with that of the cortex of *O. Ortgiesii*. We may also note that according to Knothe the mesophyll of *Oxalis articulata*, Sav. contains 'twin-crystals of calcium sulphate showing the well-known swallow-tail form' (probably also equivalent to styloids of calcium oxalate).

of definite epithelial cells in the secretory cavities as described by Fredrikson. The bulb-scales of certain species of *Oxalis* contain secretory cells side by side with secretory cavities, while in other species of this genus secretory cells alone are present (Fredrikson). Magnus's statement as to the occurrence of anastomosing septate laticiferous tubes in the root-tubers of *Tropaeolum brachyceras*, Hook. and *T. Leichllini*, Herb. Kew, still awaits confirmation. In *Tropaeolum majus*, L. the epidermis on both sides of the leaf contains tubular cells, which Irgang describes as mucilage-cells. Myrosin-cells are wanting in *Oxalis* (Chauvel).

Structure of the Petiole. According to Brunies, medullary vascular bundles (with central phloem) are not present in all the species of *Pelargonium*. In *Tropaeolum* the petiole contains isolated vascular bundles. In *Averrhoa*, *Biophytum*, *Connaropsis*, *Eichleria* and *Tropaeolum* the mechanical tissue is developed in the form of a sclerenchymatous ring, while in the caulescent species of *Oxalis* it appears as bundles of fibres developed in relation to the individual vascular strands.

For the systematic anatomy of the bulb-scales of *Oxalis* see Fredrikson, and also Chauvel.

3. Structure of the Axis. Amongst the woody members of the Order, *Averrhoa*, *Connaropsis*, *Dapania* and *Eichleria* possess pericyclic groups of bast-fibres, forming a more or less closed mechanical ring. *Dapania scandens* shows bands of secondary hard bast, while the pith of the same plant contains cells of the nature of bast-fibres.

Development of hard bast in the pericycle is met with amongst the herbaceous forms also in species of *Biophytum*, *Hypseocharis*, *Oxalis* and *Tropaeolum*. In *Tropaeolum peregrinum*, L. the cork arises in the endodermis (Magnus).

Literature: Möller, Gerberinden, Berlin, 1880, pp. 124–7 (Churco-bark).—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 104 et seq.—Hildebrand, Schutzeinricht. bei den *Oxalis*-Zwiebeln, Ber. deutsch. bot. Gesellsch., 1884, p. 108.—[Acqua, in Ann. R. Ist. bot. Roma. 1887.]—Aufrecht, Extraflorale Nekt., Diss., Zürich, 1892, p. 20 et seq. (*Impatiens glanduligera*).—[Drobnig, Wurzel-Knollen, Diss., Rostock, 1892, p. 49 et seq. (*Oxalis*).]—Guignard, Principes act., Comptes rendus, Paris, cxvii, 1893, pp. 587 and 751 et seq.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Fredrikson, Anatom.-syst. Stnd. öfver Lökstammiga *Oxalis*-arter, Akad. Afh. Upsala, 1894–5, 67 pp., Tab. i–ii.—Jönsson, Anat. Bau d. Bl., Acta Univ. Lund, xxxii, 2, 1896.—Magnus Gust., Beitr. z. Anat. der Tropaeolaceae, Diss., Heidelberg, 1898, 50 pp.—Schwendener, Gelenkpolster von *Phaseolus* u. *Oxalis*, Sitz.-Ber. Berliner Akad., 1898, xii, p. 176 et seq.—Spanjer, Wasserapparate, Bot. Zeit., 1898, i, p. 54.—Brunies, Anat. d. Geraniaceen-Blätter, Diss., Breslau, 1900, 40 pp., 1 Tab.—Brunotte, Rech. embr. et anat. sur qu. esp. d'*Impatiens* et *Tropaeolum*, Thèse, Paris, 1900, 178 pp., 10 pl.—Kliem, Regenerationsorg., Diss., Erlangen, 1900, p. 11.—Schleichert, Xerophyten bei Jena, Naturwiss. Wochenschr., 1900, p. 449 (*Geranium*).—Tunmann, Sekretdrüsen, Diss., Bern, 1900, p. 23.—[Arechavaleta, Fl. Urug., Ann. Mus. nac. de Montevideo, iii, 1901, p. 189 et seq.; cited from Chauvel.]—Haberlandt, Sinnesorgane, 1901, p. 88 et seq.—Molisch, Milchsaft u. Schleimsaft, 1901, p. 14.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 48, 50, and 75.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 313 (*Connaropsis*).—Buchenau, Tropaeolaceae, in Pflanzenreich, Heft 10, 1902, pp. 4, 5.—[Fenizia, Corpuscoli resinosi colorati nell' *Oxalis esotiche*, Riv. Ital. Sc. nat., 1902, pp. 52 and 83; abstr. in Bot. Centralbl., xciii, p. 337.]—Höhlke, in Beih. bot. Centralbl., xi, 1902, p. 42.—Irgang, Saftausscheid. Elem. u. Idioblasten bei *Tropaeolum maius*, Sitz.-Ber. Wiener Akad., cxi, Abt. 1, 1902, 9 pp., 1 Tab.—Knothe, Unbenetzb. Blätter, Diss., Heidelberg, 1902, pp. 10, 11.—Knuth, *Geranium*, in Engler, Bot. Jahrb., xxxii, 1902, p. 190 et seq.—[Preston, in Bot. Gaz., xxxiii, 1902, pp. 150–4; abstr. in Bot. Centralbl., lxxxix, p. 516.]—[Ramaley, Trich. struct. of *Erodium cicutarium*, Bot. Gaz., xxxiii, 1902, pp. 140–2.]—Chauvel, Rech. sur la fam. des Oxalidacées, Thèse, Paris, 1903, 205 pp.—[Van Tieghem, in Bull. Mus. d'hist. nat., ix, 1903, p. 287.]—Col, in Ann. sc. nat., sér. 8, t. xx, 1904, p. 128.—[Dore, Ét. bot., chim. et pharm. des *Geranium atlanticum* et *G. maculatum*, Thèse, Toulouse, 1904.]—Haberlandt, Lichtsinnesorg., 1904, p. 112 et seq., and Tab. iii.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 24.—Theorin, Växttrichom., Arkiv för Bot., iii, n. 5, 1904, p. ii; see also loc. cit., iv, n. 18, 1905, p. 7.—Netolitzky, Dikotylenbl. (Rhaphiden), 1905, p. 33.—Porsch, Spaltöffnungstypus, Jena, 1905, pp. 117–19 and Tab. iv.—Sarton, Rech. exp. sur l'anat. des pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 33 and 95 et seq. (*Geranium*).—[Holtermann, Einfluss d. Klimas, 1907, p. 217 (*Impatiens macrophylla*).]

RUTACEAE (pp. 174–182).

1. The following special characters may be added to the REVIEW OF THE ANATOMICAL FEATURES: glands, which do not project in the form of hairs, in certain species of *Boronia*; sphaerocrystalline masses of varying chemical composition (partly hesperidin); branched sclerenchymatous cells (species of *Boronia*) and enlarged terminal tracheids (*Phebalium*) in the mesophyll; groups of fibrous cells situated in the pith of *Evodia fraxinifolia*, Hook. f. The ordinary clothing hairs are unicellular or uniseriate. In a few members of the Order additional records of the differentiation of epidermal papillae or of the presence of hypoderm in the leaf have recently been published.

2. STRUCTURE OF THE LEAF. Schulze has recently investigated the structure of the leaf in a large number of genera [1]. The subsequent description is based on his work, as well as on the remaining papers cited below. Epidermal cells with mucilaginous inner membranes have been recorded in certain species of *Acmadenia*, *Adenandra*, *Agathosma*, *Barosma*, *Coleonema*, *Diosma*, *Empleurum*, *Flindersia*, *Macrostylis*, *Phellodendron*, *Skimmia*, *Toddalia* and *Zanthoxylon*. Hesperidin is not only found in the **epidermis** of the species of *Barosma*, for, according to Schulze, it occurs in the same position also in *Agathosma biophylla*, E. et Z., *Calodendron capense*, Thunb., *Dictamnus Fraxinella*, Pers., *Empleurum ensatum*, E. et Z., *Ptelea trifoliata*, L., *Skimmia japonica*, Thunb., *Toddalia aculeata*, Lam., *Zanthoxylon fraxineum*, Willd. and *Z. Pterota*, H. B. K., and, according to Duval, in *Pilocarpus Goudotianus*, Tul., *P. pennatifolius*, Lem., *P. trachylophus*, Hemsl. and *Zanthoxylon elegans*, Engl. According to Schulze, as may be pointed out here, the sphaerocrystalline masses, observed by Schaarsschmidt in alcohol-material of *Ruta* (*Haplophyllum*) *Biebersteinii*, Neilr., and regarded by him as inulin, consist neither of inulin nor of hesperidin; Geiger also states that the crystalline aggregates, which are found in the epidermal cells of *Pilocarpus trachyphyllus*, Holmes and other species of this genus (also *P. pennatifolius*, Lem.) and which have a tufted, rayed or racemose structure, cannot with certainty be regarded as consisting of hesperidin. In *Eriostemon salicifolius*, Sm. the upper epidermis consists locally of two layers. Hypoderm is found, according to Duval, in *Pilocarpus giganteus*, Engl. (composed of 2–3 layers), *P. Goudotianus*, Tul. (one layered) and *P. latifolius*, St. Hil. (1–2 layers), and, according to my own observation, in *Pagetia medicinalis*, F. v. M. (one-layered); it occurs also in the neighbourhood of the larger veins in *Evodia obtusifolia*, DC.? and in the petiole of *Ruta graveolens*, L. Papillose differentiation of the epidermal cells has been observed also in *Boenninghausenia albiflora*, Rchb. (on both sides of the leaf) and *Eriostemon salicifolius*, Sm. (only on the upper side); according to Duval (loc. cit., pp. 119 and 37 et seq.) and other authorities, it is found in species of *Pilocarpus* as well. In *Adenandra* the cuticle exhibits slight papillose irregularities. Schulze states that the upper epidermis in *Murraya exotica*, L. contains peculiar groups of small cells, and that below these groups the palisade-tissue is more strongly developed. The **stomata** are more commonly found only on the lower side of the leaf than on both sides. In most cases they are uniformly distributed over the entire surface, but exceptions to this rule are furnished by *Acmadenia* and

[1] viz. Cusparieae: *Almeidea*, *Erythrochiton*, *Ravia*; Ruteae: *Ruta*, *Boenninghausenia*, *Dictamnus*; Diosmeae: *Calodendron*, *Macrostylis*, *Diosma*, *Coleonema*, *Acmadenia*, *Adenandra*, *Barosma*, *Agathosma*, *Empleurum*; Boronieae: *Zieria*, *Boronia*, *Eriostemon*, *Phebalium*, *Correa*; Zanthoxyleae: *Evodia*, *Choisya*, *Zanthoxylon*, *Pilocarpus*; Toddalieae: *Toddalia*, *Phellodendron*, *Ptelea*, *Skimmia*; Aurantieae: *Murraya*, *Paramignya*, *Citrus*; also the genus *Flindersia*, which was formerly placed amongst the Meliaceae.

Coleonema, in which they are confined to a narrow median zone on both sides of the leaf, and by *Macrostylis*, in which they occur only on two narrow strips, situated to the right and left of the midrib on the lower surface of the leaf. Schulze describes the occurrence of subsidiary cells to the stomata in the following species: *Citrus trifoliata*, L. (4–5 subsidiary cells), *Eriostemon buxifolius*, Sm. (1–2 subsidiary cells on either side of the pore and placed parallel to it), *Crowea saligna* (two or more distinct subsidiary cells occasionally present), *Murraya exotica*, L. (4–5 subsidiary cells), *Pilocarpus pennatifolius*, Lem. (5 subsidiary cells), *Paramignya* sp. (4–5 subsidiary cells), *Ravia resinosa*, Nees et Mart. (2–4 subsidiary cells), *Skimmia japonica*, Thunb. (subsidiary cells arranged to form a rosette). The stomata of *Erythrochiton brasiliense*, Nees et Mart. require special mention; in this species there is a single neighbouring cell situated on either side of and parallel to the pore, while in surface-view a narrow crescent-shaped area, which is faintly rose-coloured, is superposed on each guard-cell; the latter phenomenon is due to interference of light causing the cell-membranes, which are thin at these points, to appear red. The **mesophyll** is bifacial or centric. In the leaves of *Agathosma lediformis*, E. et Z., which are adpressed to the axes, the mesophyll exhibits an inversion of the ordinary anatomical structure, since the palisade-tissue situated on the morphologically lower side is more strongly developed than on the upper side. Schulze met with branched sclerenchymatous cells, generally developed in relation to the terminations of the veins, in *Boronia crenulata*, Sm., *B. elatior*, Bartl., *B. ledifolia*, Gay, and *B. serrulata*, Sm.; enlarged terminal tracheids have been observed in *Phebalium*, and stone-cells in the conjunctive parenchyma of the principal veins in *Almeidea rubra*, St. Hil.

Our knowledge as to the mode of deposition of **oxalate of lime** has been extended by the following additional facts. Solitary crystals occur in the epidermis of the leaf in *Flindersia australis*, R. Br.; the epidermal cells in this case either contain a single crystal inserted in the thickened wall or undergo subdivision by irregularly orientated walls into a number of chambers, each of which includes a crystal. On the other hand, according to the investigations of Pfitzer and Guttenberg the well-known crystal-cells of *Citrus* (see also Penzig, loc. cit.), which are met with in surface sections of the leaves, are not, as stated on p. 176, epidermal structures, but belong to the ground tissue; it is only in the course of subsequent growth that they push their way between the epidermal cells. Crystal-cells occupying the same position as those of *Citrus* are found also in *Atalantia buxifolia* and *Paramignya* sp. According to Geiger (see also Duval), features characteristic of (perhaps all) the species of the genus *Pilocarpus* are the occurrence of transversely septate palisade-cells with clustered crystals in the chambers, and the blocking up of the respiratory cavities by small cells containing clustered crystals of oxalate of lime.

The following features have been recently observed in connexion with the **trichomes**. *Erythrochiton brasiliensis*, Nees et Mart. has unicellular glandular hairs, which are commonly situated above the secretory cavities and have a spherical shape. External glands with a clavate or spherical multicellular head are found in *Choisya ternata*, Kth., *Esenbeckia febrifuga*, Juss. (according to Duval), *Monniera trifolia*, L. (according to Duval), *Peganum Harmala*, L., species of *Pilocarpus*, *Zanthoxylon Pterota*, H. B. K. and other species of this genus, and *Zieria lanceolata*, R. Br. We may class with the glandular hairs the glandular structures, commonly found on the lower side of the leaf in *Boronia crenulata*, Sm., although only of isolated occurrence in *B. elatior*, Bartl.; these glands are not however differentiated as hairs, being even slightly sunk below the surface. In surface sections they appear as small round areas, composed of a small-celled tissue and surrounded by a rosette of 4–5 narrow epidermal cells. In transverse sections of the leaf these glands exhibit a thick

outer wall with a subjacent secretory tissue consisting of 2–3 layers of palisade-like cells with thin walls, and below that 2–3 further layers of rounded cells with slightly thickened walls.

Schulze records stellate hairs also in *Boronia ledifolia*, Gay and *Crowea saligna*, Sm., while those found in species of *Correa* and *Zieria* have been subjected to detailed examination by the same investigator; in *Crowea saligna* the hairs are of such small dimensions that the surface of the leaf appears smooth. The ordinary clothing hairs are unicellular or uniseriate [1].

In many of the genera Haberlandt has demonstrated a special mechanism in the **secretory cavities** [2] serving the purpose of excretion. The glands are provided with two or more (mostly four) epidermal cells of peculiar shape, which are differentiated as lid-cells, and the lateral walls of which are specially modified. The turgescence of the cells forming the wall of the gland, and the consequent pressure exerted on the secretion, together with movements resulting in the bending of the leaf-surface, lead to the formation of clefts between the lid-cells, through which emission of the secretion takes place. According to Schulze, however, the lid-cells are not present in all the members of the Order investigated by him. As regards the distribution of the secretory cavities we may first notice that, according to Pierre, they occur also in *Thoreldora cochinchinensis*, Pierre. Schulze's statement that *Zanthoxylon* (*Fagara*) *Pterota* has no secretory cavities and only possesses secretory cells requires some modification, the secretory cavities in this species being confined to the notches between the leaf-teeth; the secretory cells are found both in the bast and in the conjunctive parenchyma of the veins. Schulze again discusses the question whether the secretory structures found in *Pagetia* are of the nature of cavities or cells, and in this relation I may mention, that I have recently investigated an original specimen of *P. medicinalis*, F. v. M., and that it possesses secretory cavities and no secretory cells [3].

In most of the species examined by Schulze the **petiole** contains a ring of wood and bast.

3. Structure of the Axis. The description of the structure of the **cortex** requires the following additions. The cork arises in the subepidermal layer in *Pilocarpus*, and not in the epidermis, as was formerly stated (Geiger); cork-development also takes place subepidermally in *Murraya exotica* (Laborde). The cells of the cork are thin in *Galipea* and *Cusparia*, while in *Esenbeckia* the inner tangential walls are strongly thickened (Gamper); *Toddalia* has cork-cells thickened in the form of a horseshoe (Bocquillon). The literature cited below also furnishes additional data on the occurrence of stone-cells and of secondary hard bast. The presence of groups of fibrous cells in the pith of *Evodia fraxinifolia*, Hook. f. requires special mention (Bocquillon).

Bocquillon's paper contains a few important facts about the **secretory receptacles** found in the axis. Secretory cavities are present in the pith also in *Evodia fraxinifolia*, Hook. f., *Toddalia aculeata*, Pers., *T. paniculata*, Lam. and *Zanthoxylon hyemale*, St. Hil. The 'lacunes' recorded in the primary cortex in certain species of *Zanthoxylon*, and the 'larges lacunes' found in the wood in *Zanthoxylon Budrunga*, Wall. are no doubt in view of my earlier statements (p. 181) of the nature of mucilage-spaces. The 'glandes oléifères,' stated to occur in the bark in

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[1] Duval's statement (loc. cit., p. 119, cf. p. 27) as to the occurrence of multicellular clothing hairs in *Pilocarpus pennatifolius*, Lem., and *P. Selloanus*, Engler, is no doubt only a misprint. Uniseriate clothing hairs are, however, found in this Order, e.g. in species of *Monniera* and *Zanthoxylon*.

[2] Secretory cavities have not been observed in the root of the Rutaceae (Van Tieghem).

[3] The statements published by Tschirch's pupils (recently Stepowski, and formerly Becheraz and Sieck) as to the occurrence of medullary resin-canals in *Amyris balsamifera* probably depend on incorrect determination of the material used for the investigation.

many species, probably in all cases represent oil-cells; the statement as to the presence of secretory cavities in the bast in *Zanthoxylon Pentanome*, DC. is certainly incorrect. What Bocquillon means by 'nodules sécréteurs,' described as occurring in the pith in *Z. Tingoassuiba*, St. Hil. and *Z. alatum*, Roxb., must be made the subject of further investigation.

For the structure of the **spines** occurring in the species of *Zanthoxylon*, see Barber, Bocquillon, Lothélier and Mitlacher; these spines subsequently become elevated on a corky excrescence, which undergoes continual increase in girth at its base (the same phenomenon moreover is met with also in *Toddalia aculeata*). The structure of the leaf-spines of *Citrus* is dealt with by Mittmann, that of the stem-spines of *Maclura* by Lothélier.

Regarding the occurrence of a '*réseau de soutien*' in the subepidermal layer of the **root** in *Choisya ternata*, see Boudouresques, loc. cit.

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SIMARUBACEAE (pp. 182–188).

1. In the REVIEW OF ANATOMICAL FEATURES a number of corrections and additions are made necessary, chiefly by Jadin's comprehensive paper [1]. The following special types of stomatal apparatus have recently been recorded:

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[1] **Jadin's investigations deal with the structure of the leaf and axis in the following genera: *Quassia, Simaba, Hannoa, Mannia, Simaruba, Ailanthus, Samadera, Hyptiandra, Castela, Holacantha, Picrasme, Brucea, Picrolemma, Eurycoma, Cadellia, Suriana, Soulamea, Amaroria, Irvingia, Kirkia, Harrisonia, Picrella, Picramnia, Picrodendron,* as well as *Alvaradoa, Klainedoxa, Oldyendea,* and *Picrocardia*; in *Amaroria* the leaf only was examined.**

stomata with subsidiary cells, placed parallel to the pore (*Castela, Irvingia, Klainedoxa, Picrodendron*); stomata with 3–5 neighbouring cells resembling subsidiary cells (*Suriana*); and stomata arranged in groups (*Castela, Soulamea*). *Suriana* constitutes an exception as regards the mode of development of the cork, the phellogen in this genus arising in the inner part of the primary cortex. A composite and continuous ring of sclerenchyma in the pericycle is present also in *Rigiostachys* and *Samadera Harmandii*, Pierre: in the genera *Irvingia, Irvingella, Desbordesia* and *Klainedoxa*, which belong to the Irvingieae, there is a similar ring, which differs however in including sclerosed parenchymatous cells exhibiting U-shaped thickening; *Castela* has a fairly continuous and composite ring. Secondary hard bast is of frequent occurrence. In *Guilfoylia* the walls of the vessels bear simple pits in contact with parenchyma of the medullary rays; in *Rigiostachys*, as well as in *Brunellia* and *Neopringlea*, some of the wood-fibres are septate. Jadin records the occurrence of resin-canals at the periphery of the pith also in *Eurycoma, Hannoa* and *Oldyendea*.

Uniseriate clothing hairs are found side by side with the unicellular hairs. The deposition of oxalate of lime in the special form of small crystals of varied shape, which are situated in the mesophyll or in the epidermis of the leaf, is met with also in the genera of the Surianeae (*Cadellia, Guilfoylia, Rigiostachys* and *Suriana*). Resin-cells have been demonstrated also in species of *Irvingia* and in *Oldyendea*, as well as in the genus *Chamaelea* (*Cneorum pulverulentum*, Vent.), which Van Tieghem rightly separates from *Cneorum*. Mucilage-cells or spaces are of general distribution in the genera of the Irvingieae (*Irvingia, Irvingella, Desbordesia* and *Klainedoxa*), and in the new genus *Perrierea*, which is closely related to *Picrasma*. Other specially noteworthy features are as follows: The vertical transcurrence of the smaller veins of the leaf in *Irvingia, Klainedoxa* and *Picrodendron*; the extrafloral nectaries on the petiole in *Cadellia*, and on the midrib and occasionally on both surfaces of the leaf in *Samadera*; the heterogeneous pith found in *Harrisonia*; the subepidermal groups of fibrous cells in the stem of the leafless genus *Holacantha*; and the 'cristarque'-cells situated in the primary cortex in the genera of the Irvingieae.

2. Structure of the Leaf. In most cases the leaf is bifacial in structure, rarely (*Ailanthus excelsa*, Roxb., *Chamaelea pulverulenta*, V. T. and *Suriana maritima*, L.) centric. Papillose differentiation of the lower **epidermis** is found in the following additional species: *Ailanthus Fauveliana*, Pierre, *A. imberbifolia*, F. v. M., *A. malabarica*, DC., *Eurycoma longifolium*, Jack, *Irvingia Oliveri*, Pierre (=*Irvingella Oliveri*, V. T.), *Kirkia Williamsii*, Engl., *Oldyendea gabonensis*, Engl., *O. Klaineana*, Pierre, and, according to Van Tieghem, quite generally in *Desbordesia* and *Irvingella*. Gelatinization of the epidermis of the leaf no doubt occurs in a relatively large number of genera, e. g. in *Castela erecta*, Turp. (Börgesen and Paulsen) and in the four genera of the Irvingieae (Van Tieghem). Unfortunately Jadin placed an incorrect interpretation on these gelatinized epidermal cells, as is clearly shown by his statements regarding *Picrocardia resinosa*, Radlk. and by his figures; he regarded the gelatinized cells as divided epidermal cells and the mucilaginous membranes as hypodermal cells,—an error which is very widespread in the literature dealing with systematic anatomy (e. g. also in Vignoli's paper with reference to *Irvingia Oliveri*) and is met with over and over again. Jadin's statements as to the occurrence of tangential division-walls in the epidermis or as to the presence of hypoderm in species of *Ailanthus, Amaroria, Castela, Hannoa, Irvingia, Kirkia, Klainedoxa, Oldyendea, Picrocardia* and *Soulamea* must therefore be accepted with reserve and require critical revision. The **stomata** are provided with subsidiary cells in only a very few of the genera. In *Irvingia* and *Klainedoxa* (but not in *Irvingella* and *Desbordesia*), as well as in

Picrodendron, the stomata have subsidiary cells, which are placed parallel to the pore ; according to Börgesen, and Paulsen the same is true of *Castela*. In *Suriana* there are 3–5 neighbouring cells differentiated like subsidiary cells. Stomata are found on both sides of the leaf also in *Chamaelea pulverulenta*, V. T. and *Suriana maritima*, L. In *Castela depressa*, Turp. each group of three stomata is surrounded by four or five neighbouring cells ; in most of the species of *Soulamea*, if I understand Jadin rightly, the stomata are arranged in groups (stomates . . . réunis en plages avec 5 ou 6 cellules de bordure '), whilst in *S. Pancheri*, Brongn. et Gris they are contained in pits, like those of *Nerium*. Jadin has recently observed spicular cells in the **mesophyll** in the following additional genera : *Hyptiandra*, *Irvingia* and *Oldyendea*[1]. In *Irvingia gabonensis*, Baill. occasional cells of the spongy tissue are strongly thickened and differentiated as sclereids, while in *Castela longifolia*, Gris and *C. erecta*, Turp. the same feature is shown by isolated palisade cells. In *Irvingella* (according to Van Tieghem, but not in *Irvingia*, V. T. em.), *Klainedoxa* and *Picrodendron* the smaller **veins** are vertically transcurrent by means of sclerenchyma.

Regarding the mode of deposition of **oxalate of lime** we may add the following information. Small crystalline bodies, sometimes resembling clustered crystals, are found in the mesophyll and occasionally in the epidermis also in the remaining Surianeae (*Suriana*, *Cadellia*, *Guilfoylia*). Relatively large idioblasts occupied by solitary (e. g. in *Picramnia*) or clustered crystals (e.g. in *Brucea*) are frequently present in the mesophyll. In addition to the unicellular clothing **hairs** uniseriate hairs also occur in this Order (e. g. in *Hyptiandra*, *Picrocardia* and *Soulamea*), while in *Cadellia* the unicellular hairs are accompanied by bicellular trichomes with a short basal cell. Unicellular, two-armed clothing hairs having the shape of a T or Y are found only in *Cneorum pulverulentum* (= *Chamaelea pulverulenta*, V. T.). *C. tricoccum* merely having ordinary unicellular clothing hairs. The only additional records of the occurrence of multicellular external glands are those of *Brucea sumatrana*, Roxb. (according to Jadin) and of *Cneorum tricoccum*, L. (according to Van Tieghem). In connexion with our account of the glandular hairs we may notice the extra-floral nectaries (?) found on the petiole in *Cadellia pentastylis*, F. v. M., and appearing to the naked eye as callosities. Their epidermis consists of narrow palisade-like cells, the lumina of which terminate in the thick outer wall in the form of a cone ; beneath the epidermis there are two, or in the middle of the nectary three, layers of cells, exhibiting greater elongation and having thick lateral walls which are yellow in colour. The nectaries found in *Samadera* have not yet been subjected to a close examination ; they occur in large numbers on both surfaces of the leaf in *Locandi* (*Samadera*) *mekongensis*, Pierre and *Samadera indica*, Gaertn., while in other species of the genus two of them are situated on the midrib on the lower side of the leaf.

According to Jadin, the **petiole** for the most part has an annular fibrovascular system which frequently (according to Jadin, the only exceptions are *Alvaradoa*, *Harrisonia*, *Irvingia*, *Klainedoxa*, *Picramnia* and *Picrodendron*[2]) encloses one

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[1] The species in which spicular cells were not known or at least were not expressly stated to be present in the mesophyll are as follows : *Hannoa Klaineana*, Pierre, *H. undulata*, Planch. ; *Hyptiandra Bidwillii*, Hook. f. ; *Mannia africana*, Hook. f. ; *Oldyendea Klaineana*, Pierre, *O. gabonensis*, Engl. ; *Quassia africana*, Baill. ; *Simaba angustifolia*, Spruce, *S. Cedron*, Planch., *S. crustacea*, Engl., *S. floribunda*, St. Hil., *S. foetida*, Poepp., *S. glandulifera*, Gard., *S. insignis*, St. Hil., *S. obovata*, Engl., *S. orinocensis*, H. B. K., *S. salubris*, Engl., *S. subcymosa*, St. Hil., *S. Warmingiana*, Engl. ; *Simaruba floribunda*, St. Hil., *S. officinalis*, Macf., *S. Tulae*, Urb. According to Van Tieghem, Jadin's statement as to the occurrence of spicular cells in *Irvingia Barteri*, Hook. f. and *I. Oliveri*, Pierre is incorrect.

[2] The only point of disagreement with the above facts is the earlier statement (see p. 184,

or more medullary bundles. The species with medullary resin-canals in the axis also have them in the same position in the petiole. The fibrovascular system is commonly accompanied by pericyclic hard bast. In *Samadera* (4 species) a characteristic feature is the occurrence of concentric vascular bundles, with central phloem and peripheral xylem, at the margin of the pith. According to Van Tieghem, medullary vascular bundles are wanting in all the genera of the Irvingieae, but in the upper part of its course the closed vascular ring, formed by the fusion of seven or more isolated vascular strands derived from the axis, has two inversely orientated bundles situated in the pericycle. Lastly, according to my own investigation, the petiole of *Suriana* contains only a single arc-shaped vascular bundle, while in *Rigiostachys* there is an annular vascular system, which may be either closed or open.

3. STRUCTURE OF THE AXIS. With regard to the structure of the **wood** we may add that in *Irvingia gabonensis*, Baill. it shows alternating zones of wood-fibres and wood-parenchyma (Lecomte, see also Van Tieghem), that in *Irvingella* and *Klainedoxa* the wood-parenchyma is rather abundant (Van Tieghem), and that septate wood-prosenchyma occurs also in *Rigiostachys*.

According to Jadin, the species investigated by him also for the most part show isolated groups of bast-fibres in the **pericycle**. Jadin distinctly mentions the occurrence of a more or less continuous and composite ring of sclerenchyma in the following additional species : *Castela depressa*, Turp., *Picramnia venicosa*, Tul., and *Samadera Harmandii*, Pierre ; according to Van Tieghem, a composite and continuous ring of sclerenchyma, distinguished by the inclusion of U-shaped sclerosed cells, occurs in the four genera of the Irvingieae. In the leafless species, *Holacantha Emoryi*, A. Gray, hard bast appears to be wanting in the pericycle ; instead there are subepidermal groups of fibres with intermediate assimilatory tissue of the nature of palisade. The pericycle of *Rigiostachys* contains a composite and continuous ring of sclerenchyma, which splits open in the course of the subsequent secondary growth. Regarding the pericycle of *Ailanthus glandulosa* and *Simaruba amara*, see also Pitard, loc. cit.

As a rule the **cork** arises subepidermally ; this is the case in all the genera investigated by Jadin with the exception of *Suriana*, *Amaroria* and *Soulamea*, in the genera of the Irvingieae (according to Van Tieghem) and in *Rigiostachys*. In *Suriana* the cork develops in the inner part of the primary cortex ; in *Amaroria* and *Soulamea* its place of origin has not yet been determined. Cork-cells with one-sided or U-shaped thickening (affecting the inner tangential walls) occur in *Irvingia* and have also been observed in the Asiatic species of *Irvingella* and in *Klainedoxa Trillesii*, Pierre (Van Tieghem).

The primary **cortex** occasionally contains ordinary stone-cells, which in *Castela* and *Samadera* are thickened in the form of a horse-shoe. In the genera of the Irvingieae, according to Van Tieghem, there are two layers of what he calls 'cristarque'-cells, i. e. cells which mostly exhibit U-shaped thickening, and each of which includes a solitary crystal, or rarely (*Irvingia*) a clustered crystal ; one of these layers is subepidermal in position, the other is endodermal. These 'cristarque'-cells, it may be added, are also present in the petiolar tissue. Development of secondary hard bast is very common, although rare amongst the Irvingieae. Van Tieghem found stone-cells in the secondary bast in species of *Desbordesia* and *Klainedoxa*.

The structure of the **pith** in *Harrisonia* requires special mention. The medullary tissue is heterogeneous, small thick-walled cells being distributed in a reticulate manner amongst larger cells with thin walls.

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foot-note) as to the absence of medullary bundles in *Brucea* ; Jadin did not investigate the petioles of *Brunellia*, *Castela*, *Dictyoloma* and *Picraena*, in which medullary bundles have likewise been previously recorded as absent.

In amplification of the earlier statements regarding the occurrence of medullary **resin-canals** in the Simarubaceae the following details may be quoted from Jadin's work.

Resin-canals are found in the following additional species: *Ailanthus calycina*, Pierre, *A. excelsa*, Roxb., *A. Fauveliana*, Pierre, *A. imberbifolia*, F. v. M., *A. malabarica*, DC.; *Brucea paniculata*, Lam., *B. sumatrana*, Roxb.; *Eurycoma longifolium*, Jack (in opposition to Syst. Anat. p. 187); *Hannoa Klaineana*, Pierre, *H. undulata*, Planch.; *Oldyendea gabonensis*, Pierre, *O. Klaineana*, Pierre; *Picrasma ailanthoides*, Planch., *P. javanica*, Bl., *P. nepalensis*, Benn, *P. quassioides*, Benn., *P. Tweedii*, Planch.; *Simaba angustifolia*, Spruce, *S. floribunda*, St. Hil., *S. glandulifera*, Gardn., *S. insignis*, St. Hil., *S. obovata*, Engl., *S. orinocensis*, H. B. K., *S. subcymosa*, St. Hil., *S. suffruticosa*, Engl. (contrary to Syst. Anat., loc. cit.); *Soulamea amara*, Lam., *S. elegans*, Vieill., *S. Mülleri*, Brongn. et Gris, *S. Pancheri*, Brongn. et Gris, *S. tomentosa*, Brongn. et Gris, *S. trifoliata*, Baill. On the other hand, Jadin did not meet with resin-canals in the genera *Alvaradoa*, *Cadellia*, *Castela*, *Harrisonia*, *Holacantha*, *Hyptiandra*, *Irvingia*, *Kirkia*, *Klainedoxa*, *Mannia*, *Picramnia*, *Picrella*, *Picrodendron*, *Quassia*, *Samadera*, *Suriana*, and also not in *Rigiostachys* and *Guilfoylia*. As a general rule the presence of medullary resin-canals is a generic character. The sole exception has proved to be *Simaba*, since some of the species of this genus have no medullary resin-canals (see Syst. Anat. p. 187; according to Jadin, this is also the case in *S. crustacea*, Engl., *S. foetida*, Poepp. and *S. salubris*, Engl.).

Resin-cells have been recorded by Jadin, Guérin and Van Tieghem in the following additional cases:—in the mesophyll, in *Ailanthus calycina*, *A. Fauveliana*, *A. imberbifolia* and *A. malabarica*; in the primary cortex and in the leaf, in *Chamaelea pulverulenta*; in the primary cortex, in *Harrisonia Brownei*, Juss., *Irvingia Duparqueti*, V. T., *I. gabonensis*, Baill. and *I. tenuifolia*, Hook. f.; accompanying the pericycle in the axis and the vascular bundles of the veins in the leaf, in *Oldyendea Klaineana*, Pierre. In the genera *Irvingia*, *Klainedoxa* and *Picrodendron* (according to Jadin) mucilage-cells are found in the primary cortex of the axis and in the ground-tissue of the petiole, while mucilage-lacunae are present in the pith of the axis. Mucilage-spaces, similar to those of *Irvingia*, occur also in *Perriera* (according to Guérin), being situated in the axis, in the rachis of the leaf, in the petiole, and in the larger veins of the leaf. The genera *Desbordesia*, *Irvingella*, *Irvingia* and *Klainedoxa* (according to Van Tieghem) have mucilage-cells which either are isolated or form groups and are found in the primary cortex, and in some cases in the pith as well.

For the structure of the spiny aerial **roots** of *Klainedoxa spinosa*, V. T., see Van Tieghem, 1905, loc. cit.

Appendix: *Koeberlinia*.

A connected account of the anatomy of the genus *Koeberlinia* may be given at this point apart from the general description of the Simarubaceae. The affinities of the genus are not yet quite clear, but it is regarded by Engler and Van Tieghem as constituting an independent Order (Koeberliniaceae). The only species of the genus, *Koeberlinia spinosa*, Zucc. is a leafless and spiny shrub; from an anatomical point of view, it is specially characterized by the possession of secretory canals situated in the bast, the composite and continuous ring of sclerenchyma in the pericycle, the pericyclic cork-development, the simple perforations in the vessels and the wood-fibres which have thick walls and slit-shaped pits with a small border.

The vascular bundles of the axis are separated by rather broad medullary rays, the outer ends of which are enlarged in the form of a wedge between the bast-portions. Opposite the bast-portions the pericycle contains massive bundles of hard bast, which are joined to form a continuous strengthening ring by means of stone cells. The bast-portions exhibit a peculiar stratification into darker zones, composed of parenchyma and lighter zones, consisting of compressed sieve-tubes.

The secretory canals originate in the parenchymatous zones, and either lie singly or several of them are placed side by side; in the former case they take up the whole breadth of the band of parenchyma. In later stages sclerosed cells are found in the bast and in the medullary rays of the bast; similar cells occur also in the primary cortex. The cork develops in the pericyclic parenchyma on the inner side of the strengthening ring and consists of cells, the outer tangential walls of which are strongly thickened. Phelloderm is present, its cells having lignified walls. The epidermis consists of cells exhibiting palisade-like elongation and having all their walls thickened, especially the outer ones. In the absence of leaves the outer part of the primary cortex is differentiated as a palisade-tissue of several layers, while the inner part consists of isodiametric cells. The only kind of trichomes yet observed are unicellular conical clothing hairs with thick walls. Oxalate of lime is found in the pith in the form of solitary crystals.

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OCHNACEAE (pp. 188–190).

In the course of the last few years the Ochnaceae (sensu Bentham and Hooker) have formed the subject of detailed systematic, morphological and anatomical studies by Van Tieghem [1]. On the basis of his investigations Van Tieghem regards the genera *Ochna*, *Ouratea*, *Brackenridgea* and *Elvasia* (belonging to the Ochneae) as constituting an independent Order, the Ochnaceae (with no less than 57 genera); *Tetramerista* (see Syst. Anat., p. 189) is excluded, while the four genera above named are split up into a number of others. In the same way the genera of the Luxemburgieae with the exclusion of *Wallacea* and the addition of seven other genera are established as a separate Order, the Luxemburgiaceae. In the following description, in which Van Tieghem's system of classification is adopted, we shall deal with the anatomical characters presented by leaf and axis [2], first in the Ochnaceae sens. str., then in the Luxemburgiaceae, and lastly in *Wallacea* (Order: Wallaceaceae, V. T.), as well as in *Euthemis* (formerly Tribe Euthemideae, Order Euthemidaceae, V. T.).

[1] I merely adopt Van Tieghem's nomenclature of the genera and species in the above description as a matter of convenience. For a criticism of his systematic theories see Gilg, Beitr. z. Kenntnis d. Ochnaceen, Festschrift für Ascherson, Leipzig, 1904, p. 97 et seq.

[2] As far as the structure of the wood is concerned there is nothing to add to the older statements (Syst. Anat., p. 189), since Van Tieghem devoted very little attention to it.

I. OCHNACEAE, VAN TIEGHEM.

1. ANATOMICAL FEATURES. Two features are primarily characteristic of the whole taxonomic group, viz. (*a*) the presence in the branches, petioles, median and lateral veins of a layer of cells ('cristarque'), which is normally situated in the second layer beneath the epidermis and is composed of cells with U-shaped thickening, each of which encloses a clustered crystal; and (*b*) the occurrence of cortical vascular bundles. The cork invariably develops superficially, viz. in the epidermis or in the first layer of cells of the primary cortex. A hairy covering is rarely present, and then consists exclusively of uni- or multicellular clothing hairs. Oxalate of lime is mostly deposited in the form of clustered crystals.

The anatomy of the genera *Elvasia*, *Vaselia*, *Trichovaselia* and *Hostmannia*, which Van Tieghem groups together as the Elvasioideae, differs from that of the remaining members of the Order (Ochnoideae) in the occurrence on the upper side of the leaf of a hypoderm, composed of fibrous cells which show a transverse arrangement, and in the presence in the pith of the petiole of an arc of wood and bast, showing normal orientation (with the wood on the upper side). In certain cases the leaf contains gelatinized or papillose epidermal cells or spicular fibres, while in some of the species of *Trichouratea* the stomata are placed in pits.

2. STRUCTURE OF THE AXIS. In view of the systematic importance of the layer of cells, termed the 'cristarque,' the structure of the axis may in this case be considered before that of the leaf. The 'cristarque[1]' constitutes the second layer of the primary cortex, and is composed of lignified cells, with U-shaped thickening (on the inner tangential and radial walls) and each enclosing a clustered crystal of oxalate of lime; the latter sometimes shows a slight sphaerocrystalline structure. The 'cristarque' is not quite continuous, being interrupted by thin-walled passage-cells, which in general correspond in position with the stomata in the epidermis. Very considerable diversity is shown in the mode of differentiation and in the position of the 'cristarque' in the individual genera and within the limits of one and the same genus, often varying, in fact, from species to species; these differences are of systematic importance. The number of thin-walled cells may be small or large; as a consequence, we get all transitions between an almost continuous 'cristarque' and a zone, composed only of a small number of 'cristarque'-cells In certain species (e. g. of *Ouratea*, *Campylospermum*, *Campylocercum*, *Cercanthemum*, *Cercinia*, &c.) the 'cristarque' is apparently not situated in the second cell-layer of the primary cortex, since it is separated from the epidermis by more than one (2, 3 or 4) layer of cells; but an investigation of the course of development in these cases shows that the subepidermal layer has undergone subsequent division into 2–4 layers of cells, so that the 'cristarque' nevertheless belongs to the second cortical layer. The thin-walled cells found in the discontinuous 'cristarque' undergo subsequent sclerosis in many species, the cells being affected equally on all sides. In certain species the 'cristarque'-sheath is further strengthened by uniform sclerosis of the cells of one or more layers of the primary cortex; these are either situated on the inner side of the 'cristarque,' or beneath the epidermis (including the layers of cells produced by the division of the subepidermal layer), or in both these regions. Only in very rare cases (*Diphyllanthus Duparquetianus*, V. T.) do the cells of the (here well-developed) 'cristarque' contain prismatic crystals in place of the

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[1] In the rhizomes and roots which have been examined, the layer of cells known as 'cristarque' is completely absent.

clustered crystals. As regards the remaining characters of the **primary cortex** we may notice that it frequently contains clustered crystals and sclerosed cells, in some cases also prismatic crystals (species of *Campylospermum, Spongopyrena, Diporidium, Monoporidium, Porochna*) or cells in which the structure of the wall is similar to that of the 'cristarque'-cells (species of *Cercinia, Ochnella, Vaselia*; in the last two genera occupied by prismatic crystals) or unequally thickened cells containing prismatic crystals (*Trichovaselia*). The endodermis is as a rule not distinctly differentiated; it is only in a few species that it includes 'cristarque'-cells with clustered crystals; in these cases there is a secondary endodermal 'cristarque,' which is however only rarely well-developed. The above-mentioned **cortical vascular bundles** owe their origin to the fact that of the three bundles, passing out from the stem into the leaf situated immediately above, the two laterals in most cases depart from the vascular ring of the axis some considerable distance below the node (in *Diporidium* alone do they arise only in the uppermost part of the internode); as a consequence no cortical vascular bundles are present in the lower part of the internode. In most cases there are two of these cortical bundles, but occasionally (*Camptouratea*) a larger number is found in the uppermost portion of the internode owing to branching. The bundles are accompanied by groups of bast-fibres. In most members of the Order the **pericycle** is formed by isolated groups of bast-fibres, but occasionally an almost or completely continuous and composite ring of sclerenchyma is developed (e. g. in species of *Trichouratea, Dasouratea, Cercouratea, Microuratea, Gymnouratella, Campylospermum, Diphyllanthus, Monelasmum, Ochnella*) by sclerosis of the cells situated between the groups of bast-fibres. The **secondary bast** sometimes contains clustered crystals, but rarely (*Diporidium purpureum*, V. T., *Porochna Autunesii*, V. T.) prismatic crystals; sclerosed cells[1] may also be present; fibres (*Diporidium purpureum, Hostmannia*) or unequally sclerosed cells containing prismatic crystals (*Elvasia, Trichovaselia*) are very rare. The mode of development of the **cork,** whether epidermal or subepidermal, is on the whole only a specific character. The walls of the cork-cells are either thin, or the tangential walls are sclerosed. Phelloderm may or may not be present. It has either thin walls or some or all of its cells exhibit U-shaped thickening; complete sclerosis of the cells is rare; in a few cases (species of *Porochna* and *Diporochna*) the cells of the phelloderm contain small prismatic crystals.

Epidermal cork-development has been recorded in: *Camptouratea* pro parte, *Stenouratea, Notouratea, Plicouratea* pro parte, *Ancouratea* pro parte, *Diouratea, Trichouratea* (almost always), *Pilouratea, Dasouratea, Ouratea* pro parte, *Isouratea, Polyouratea, Tetrouratea, Cercouratea* pro parte, *Microuratea* pro parte, *Setouratea, Ouratella, Gymnouratella, Bisetaria, Campylospermum* pro parte, *Campylocercum* pro parte, *Cercanthemum* pro parte, *Diphyllopodium, Spongopyrena, Rhabdophyllum, Monelasmum* pro parte, *Exomicrum* pro parte, *Ochnella* pro parte, *Polyochnella* pro parte, *Discladium, Diporidium* pro parte, *Monoporidium, Polythecium* pro parte, *Heteropodium, Ochna, Diporochna, Pleuroridgea, Campylochnella, Vaselia*; subepidermal cork-development is found in: *Camptouratea* pro parte, *Plicouratea* pro parte, *Ancouratea* pro parte, *Trichouratea foliosa*, V. T., *Hemiouratea, Volkensteinia, Ouratea* pro parte, *Cercouratea* pro parte, *Microuratea* pro parte, *Campylospermum* pro parte, *Campylocercum* pro parte, *Cercanthemum* pro parte, *Cercinia, Notocampylum, Diphyllanthus,*[1] *Monelasmum* pro parte, *Exomicrum* pro parte, *Ochnella* pro parte, *Polyochnella* pro parte, *Diporidium* pro parte, *Polythecium* pro parte, *Porochna, Brackenridgea, Elvasia, Trichovaselia, Hostmannia.*

The **pith** becomes lignified at an early stage. In addition to clustered crystals the pith in many species includes cells which are sclerosed on all sides;

[1] Van Tieghem does not describe the detailed structure of the sclerosed cells in the bast; regarding this point, see Syst. Anat., p. 189.

in *Notouratea undata*, V. T. occasional cells exhibit thickening of the wall similar to that found in the 'cristarque'-cells.

3. Structure of the Leaf. Three vascular bundles pass out into the leaf or petiole as the case may be; the median bundle of the three branches off from the vascular ring of the axis at the node, while the two lateral strands traverse the upper portion of the internode as cortical bundles; each of the two lateral strands gives off a small branch which supplies the stipules or the ligule. The vascular bundles on entering the petiole soon unite to form a ring of wood and bast, which is in most cases completely closed (except in *Microuratea cassinifolia*, V. T.) and has a central pith; the lower surface of this annular system is convex, while the upper is concave or flat; bundles of fibres, which are mostly distinct from one another, accompany the bast on its outer side. The Elvasoideae are specially distinguished from the Ochnoideae by the fact that the pith of the petiole contains an arc of wood and bast, comprising several vascular bundles, which exhibit normal orientation, the wood being placed on the upper side. Medullary bundles, it is true, are exceptionally present also in two members of the Ochnoideae (*Campylospermum angulatum*, V. T. and *Notocampylum Mannii*, V. T.), but the bundles in these cases show inverse orientation, the wood being on the lower, the bast on the upper side. In this connexion we may notice that the pith contains a transverse band of fibres in *Trichouratea Gardneri*, V. T., two bands of fibres in species of *Spongopyrena*, and elements resembling 'cristarque'-cells in species of *Rhabdophyllum*, *Polythecium* and *Diporochna*. In *Campylospermum nigrinerve*, V. T., five cortical vascular bundles, which are united to form an arc, are found on the outer and lower side of the vascular ring. The 'cristarque' (and we may deal first with the outer one, which is situated in the second cell-layer beneath the epidermis) is generally present also in the petiole, and then exhibits the same modifications as in the branch. It is more or less typically differentiated. Only in rare cases is there merely a single layer of cells between it and the epidermis; as a rule there are 2, 3, 4 or even 6–8 intervening layers of thin-walled cells, which have been formed by subsequent division of the subepidermal layer. The outer 'cristarque' is rarely absent (e. g. in species of *Camptouratea*, *Tetrouratea* and *Campylospermum*); still more rarely (*Diphyllanthus*) do the 'cristarque'-cells contain prismatic in place of clustered crystals. In some of the species there is, as in the branch, an inner (endodermal) 'cristarque' in addition to the outer one, this inner 'cristarque' varying in the extent of its development. Lastly, elements resembling 'cristarque'-cells are occasionally found also in the cortical tissue (species of *Ouratea*, *Rhabdophyllum*, *Polythecium*, *Diporochna*, *Brackenridgea*, *Trichovaselia*); in other cases the cortex contains cells which are sclerosed on all sides.

Regarding the structure of the lamina of the leaf the following facts may be mentioned. In most of the species the leaf is bifacial in structure, the palisade-tissue consisting of a single layer of cells. Centric structure with palisade-tissue on both sides of the leaf is found only in *Pilouratea ovalis*, V. T. and *Dasouratea Hassleriana*, V. T.; in certain species of *Cercouratea* and *Diphyllopodium* the palisade-tissue is not typically differentiated. In many species[1] a varying number of the epidermal cells of the leaf have mucilaginous inner membranes, these cells sometimes penetrating deeply into the mesophyll. *Ouratea guianensis*, Aubl., *O. rubescens*, V. T. and *Cercouratea Magdalenae*, V. T.

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[1] viz. species of *Camptouratea*, *Stenouratea*, *Notouratea*, *Plicouratea*, *Ancouratea*, *Trichouratea*, *Villouratea*, *Hemiouratea*, *Ouratea*, *Polyouratea*, *Tetrouratea*, *Cercouratea*, *Microuratea*, *Setouratea*, *Ouratella*, *Gymnouratella*, *Campylospermum*, *Campylocercum*, *Cercanthemum*, *Cercinia*, *Spongopyrena*, *Monelasma*, *Ochnella*, *Polyochnella*, *Discladium*, *Diporidium*, *Monoporidium*, *Polythecium*, *Ochna*, *Diporochna*, *Brackenridgea*, *Pleuroridgea*, *Campylochnella*.

are distinguished by possessing sclerosed epidermal cells, the inner ends of which are narrowed in the form of a cone and penetrate into the palisade-tissue. The epidermal cells of *Notouratea inundata*, V. T. have lignified thickening bands on their lateral walls. Formation of papillae has been recorded in *Notouratea inundata*, V. T. (knob-shaped cuticular papillae on the lower side of the leaf), *Trichouratea foliosa*, V. T. (on the upper side), *Diphyllopodium Klainei*, V. T. and *Exomicrum coriaceum*, V. T. (on the lower side). Not uncommonly the walls of the epidermal cells are completely or partially lignified. In most of the species the **stomata** are confined to the lower surface of the leaf. But in *Pilouratea ovalis*, V. T. and *Isouratea humilis*, V. T., they occur on both sides, and in species of *Ouratea*, *Cercinia*, *Polyochnella*, *Pleuroridgea*, *Campylochnella*, *Elvasia*, *Vaselia*, *Trichovaselia* and *Hostmannia*, stomata are also present on the upper side, though only on and near the midrib (in *Campylochnella* they occupy the same position with reference to the lateral veins as well). Van Tieghem's statement as to the absence of subsidiary cells is not quite in agreement with my earlier observations. In *Trichouratea subvelutina*, V. T. the stomata (also those on the axis) are found in special pits ('Spaltöffnungskrypten'). The occurrence of a **hypoderm** composed of transversely placed fibrous cells, and situated beneath the epidermis of the leaf in the Elvasioideae, has already been referred to above. Other special features, noticed in the **mesophyll**, are as follows :—large solitary crystals (*Ouratea Leprieuri*, V. T.) ; ' cristarque '-cells, occasionally forming groups (species of *Camptouratea*, *Ouratea*, *Campylospermum*, *Cercanthemum*, *Rhabdophyllum*); sclerosed isodiametric cells (*Ouratea gigantophylla*, V. T.) ; and lastly, spicular fibres, which generally branch off from the sclerenchyma of the veins, run vertically through the mesophyll or traverse it in all directions, and in most cases ultimately spread out beneath the epidermis (in a large number of species [1]). The vascular system of the lateral **veins** is provided both above and below with a group of sclerenchymatous fibres, and is separated by two layers of cells from the epidermis. The inner of these two layers, which may be regarded as equivalent to an endodermis, is generally constituted by a ' cristarque,' containing clustered crystals, and must be considered as a continuation of the outer ' cristarque ' of the branch, petiole and midrib. The ' cristarque ' of the lateral veins is developed either on both the upper and lower sides of the vascular system, or (very commonly) only on the upper side ; but in a few cases (viz. in the Elvasioideae, in which palisade-tissue is met with also in the lateral veins) it is confined to the lower side. The ' cristarque ' is very seldom imperfectly developed. Owing to sclerosis of the two layers of cells situated between the bundles of fibres and the epidermis, the lateral veins in many species [2] ultimately become vertically transcurrent. The

[1] viz.: *Camptouratea agrophylla*, V. T., *C. ilicifolia*, V. T., *C. spinulosa*, V. T.; *Plicouratea granulosa*, V. T.; *Ancouratea hemiodonta*, V. T.; *Diouratea cardiosperma*, V. T.; *Trichouratea Blanchetiana*, V. T., *T. caulipila*, V. T., *T. floribunda*, V. T., *T. foliosa*, V. T., *T. rufidula*, V. T., *T. salicifolia*, V. T.; *Dasouratea Hassleriana*, V. T.; *Volkensteinia Theophrasta*, Keg.; *Ouratea angulata*, V. T., *O. castaneifolia*, Engl., *O. coccinea*, Engl., *O. crassifolia*, Engl., *O. cubensis*, Urb., *O. disticha*, V. T., *O. Glaziovii*, V. T., *O. heterodonta*, V. T., *O. macrophylla*, V. T., *O. panamica*, V. T., *O. Purdieana*, V. T., *O. Riedeliana*, Engl., *O. rupununiensis*, Engl., *O. Spruceana*, Engl.; *Isouratea humilis*, V. T., *I. spectabilis*, V. T.; *Cercouratea curvata*, V. T., *C. repens*, V. T., *C. verruculosa*, V. T.; *Microuratea pygmaea*, V. T.; *Campylospermum angulatum*, V. T., *C. Baroni*, V. T., *C. Chapelieri*, V. T., *C. denudatum*, V. T., *C. Hildebrandtii*, V. T., *C. nigrinerve*, V. T., *C. ovale*, V. T., *C. sculptum*, V. T.; *Cercanthemum lanceolatum*, V. T.; *Notocampylum Mannii*, V. T.; *Rhabdophyllum calophyllum*, V. T., *R. paniculatum*, V. T.; *Monelasma Zenkeri*, V. T., *M. umbricola*, V. T.; *Polythecium madagascariense*, V. T.; *Brackenridgea Hookeri*, A. Gray, *B. nitida*, A. Gray, *B. palustris*, Bartel.

[2] viz. species of the genera: *Camptouratea*, *Trichouratea*, *Ouratea*, *Microuratea* (in almost all the species), *Campylospermum*, *Cercanthemum*, *Cercinia*, *Ochnella*, *Polyochnella*, *Discladium*, *Diporidium*, *Polythecium*, *Ochna*, *Porochna*.

structure of the midrib of the leaf, at least in its lower portion, is similar to that of the petiole (see above).

A hairy covering has only been observed in a few genera and species, and is composed exclusively of clothing hairs. These are unicellular (*Trichouratea, Pilouratea, Villouratea ?, Dasouratea ?, Hemiouratea, Trichovaselia*) or bicellular, and a third cell often occurs in the latter case owing to the division of the lower cell by means of a longitudinal or oblique wall (*Diporochna*). In other cases (*Trichouratea*) the hairs are uniseriate and consist of a larger number of cells. The unicellular trichomes vary in length; in *Trichouratea* they are sometimes united in bundles of two or three.

2. Luxemburgiaceae.

1. Review of the Anatomical Features. The Luxemburgiaceae, like the Ochnaceae, are characterized by the possession of cortical strands (leaf-traces); cork-formation likewise takes place superficially in the epidermal or subepidermal layer of cells. The pericycle is formed by isolated groups of bast-fibres. The structure of the leaf is bifacial and the stomata are found exclusively on the lower side of the leaf. There is no hairy covering (apart from the glandular shaggy hairs). Oxalate of lime is deposited in the form of clustered or solitary crystals.

The genera of the Godoyeae are distinguished by the presence of medullary bundles in the branch; these are composed either of vessels and fibrous cells (' fibrovasculaires,' e. g. in *Godoya, Planchonella* and *Rutidanthera*) or of a strand of soft bast and fibrous cells (' fibrocriblés,' e.g. in *Cespedesia* and *Fournieria*). Other characters distinctive of the Godoyeae are the stratification of the phloem into hard and soft bast, and the occurrence of characteristic glandular shaggy hairs (' franges sécrétrices ') on the stipules and sepals. On the other hand, medullary bundles and glandular hairs are wanting in the two other subdivisions of the Luxemburgiaceae, viz. the Luxemburgieae (with *Luxemburgia, Periblepharis, Plectanthera, Epiblepharis* and *Hilairella*) and the Blastemantheae (with *Blastemanthus* and *Poecilandra*); the Blastemantheae however, like the Godoyeae, have a stratified bast, while in the Luxemburgieae there is no hard bast.

Among special features of the structure of the leaf, we may name: the gelatinization of the epidermis; the occurrence of spicular fibres in the mesophyll; the development of an endodermal ' cristarque ' in the lateral veins; and the occurrence of vertically transcurrent lateral veins.

2. Structure of the Leaf. The leaf is bifacial in structure. **Epidermal cells** with mucilaginous inner membranes are found in *Luxemburgia, Epiblepharis* and *Hilairella*. The stomata are confined to the lower side of the leaf; in *Godoya* they are crowded together in groups in the narrow meshes formed by the network of veins. Sclerenchymatous fibres, running freely in the **mesophyll**, have been observed in the genera *Rutidanthera, Cespedesia, Fournieria* and *Blastemanthus*; in some cases (*Blastemanthus*) they form a continuous layer beneath the upper epidermis. The lateral **veins** are often vertically transcurrent by means of sclerenchyma (*Luxemburgia* pro parte, *Periblepharis, Godoya, Planchonella, Rutidanthera, Blastemanthus, Poecilandra*). An endodermal 'cristarque' containing clustered crystals is stated to occur in species of *Luxemburgia, Plectanthera, Epiblepharis, Hilairella, Cespedesia, Fournieria* and *Blastemanthus*, whilst *Poecilandra* alone has a ' cristarque ' containing solitary crystals. In all the genera except *Poecilandra* this layer is confined to the upper side of the vascular system, while in *Poecilandra* it is present on both sides. The vascular bundles, which pass out into the leaf, unite low down in the **petiole** or in the midrib to form a ring, the pericycle of which contains fibrous cells. In *Hilairella* the pith of this ring of bundles

contains a strand of bast with a band of wood on either side of it, while in *Godoya*, *Planchonella*, *Rutidanthera*, *Cespedesia* and *Fournieria* it includes from two to four arcs of wood and bast exhibiting diverse orientation and situated one above the other; in *Blastemanthus* one or two vascular bundles, and in *Poecilandra* an arc of normally orientated bundles, are found in the pith.

The glandular **shaggy hairs**, occurring on the stipules and sepals in all the Godoyeae, are 2–5 mm. in length and are distinguished by having a secretory palisade-like epidermis. Beneath the latter lies a layer of cells containing clustered crystals, and within this a vascular bundle, with an enveloping sheath of fibres.

3. Structure of the Axis. The pericycle is invariably composed of isolated groups of bast-fibres. The **cork** develops in the epidermis (*Epiblepharis*, *Hilairella*, *Godoya*, *Fournieria*, *Blastemanthus*) or in the subepidermal layer of cells (*Luxemburgia*, *Periblepharis*, *Plectanthera*, *Planchonella*, *Rutidanthera*, *Cespedesia*, *Poecilandra*). The walls of the cork-cells are either thin or sclerosed; in the latter case they may be sclerosed equally on all sides or in the shape of a U. Phelloderm may or may not be developed; when present it is sometimes sclerosed. The primary **cortex** occasionally contains stone-cells and oxalate of lime in the form of clustered or solitary crystals. In *Periblepharis* it includes isolated fibrous cells, while in *Godoya* the inner part of the primary cortex is lacunar. The cortical bundles, which are accompanied by groups of sclerenchymatous fibres, vary in number; there are often 4–6; in *Fournieria scandens*, V. T. there are 16, in *Blastemanthus* and *Poecilandra* only 2. The presence or absence of secondary hard bast has already been dealt with in the review of the anatomical features. When hard bast is present the appearance of a transverse section through the phloem-groups, and the intervening medullary rays with their expanded outer ends, quite recalls the similar features seen in the branch of the lime.

The following details may be added regarding the **medullary bundles** found in the Godoyeae. In *Godoya*, *Planchonella* and *Rutidanthera* the bundles are made up of vessels and fibres. In the two genera first named there are 8–20 (mostly 10) of these bundles, arranged in a ring, while in *Rutidanthera* the bundles are very numerous and irregularly distributed through the whole of the pith, except in its central portion. Each bundle consists of a group of fibrous cells and of a xylem-ray comprising a row of spirally thickened and pitted vessels, which usually show radial arrangement; the vessels exhibit a progressive increase in size from without inwards, and are developed centripetally, exactly as in the case of the xylem-rays in the radial bundle of a root. In *Godoya* and *Planchonella* the xylem-ray is directed outwards, the group of fibrous cells being placed at its inner end, while the outer end and the lateral surfaces of the xylem-ray are surrounded by a layer of unlignified tissue belonging to the pith. In *Rutidanthera*, on the other hand, the xylem-ray is embedded in one side of the group of fibres, the latter extending round the lateral surfaces of the xylem-strand; the ray of wood in this genus is moreover occasionally not situated on the outer side of the group of fibres, but internal or lateral to it. The medullary bundles found in *Cespedesia* and *Fournieria* have an essentially different structure, being composed of a strand of phloem and a group of fibres. In *Cespedesia* the phloem-group is for the most part embedded in the inner margin of the well-developed bundle of fibres; in some cases, however, it is situated at the outer margin or laterally and may occasionally be absent altogether. The phloem-group develops in the centrifugal direction. In *Fournieria* the strand of phloem is generally surrounded by a sheath of one or two rows of fibrous cells; it may, however, also be wanting. The bundles in *Cespedesia* and *Fournieria* exhibit an irregular arrangement, and are present in large numbers. It is specially to be noted that the medullary

bundles of the Godoyeae are cauline, so that they are not connected with the vascular strands of the stele.

We may add that in all the Godoyeae the medullary bundles become converted into typical vascular bundles in the axis of inflorescence. Strands of phloem appear in relation to the vessels and fibres, constituting the medullary bundles of *Godoya*, *Planchonella* and *Rutidanthera*, whilst vessels are added to the groups of phloem and fibres in the medullary bundles of *Cespedesia* and *Fournieria*. But the arrangement and previous orientation of the wood and bast is for the most part retained.

On the genera Wallacea and Euthemis.

In its anatomical structure the genus *Wallacea*, which Van Tieghem excludes from the Luxemburgiaceae, really shows quite a number of points of agreement with the latter, as is evidenced by Van Tieghem's own statements; these points of similarity are the cortical vascular bundles (six in number, each strengthened by an arc of fibres), the nature of the pericycle (formed by small isolated bundles of fibres), the superficial (subepidermal) development of the cork, the cells exhibiting U-shaped thickening, and also the presence of secondary hard bast (in small groups). The outer ends of the primary medullary rays of the bast are not broadened in the form of a wedge. The structure of the petiole is particularly striking; there is a ring of bundles, the pith of which contains two superposed vascular strands, of which the lower one exhibits normal, the upper one inverse orientation of wood and bast. On either side of the vascular ring four cortical bundles are found; these are situated one above the other, and consists of a central mass of xylem, enveloped by a ring of soft bast and fibres. The structure of the leaf of *Wallacea* is bifacial, the stomata being confined to the lower side. The lateral veins are not vertically transcurrent. Oxalate of lime occurs in the form of clustered and solitary crystals (the latter in the lateral veins).

According to Van Tieghem, the genus *Euthemis* is specially distinguished by the possession of large mucilage-cells situated in the pith and cortex of the branches and in the mesophyll.

Literature: Barteletti, Studio monogr. int. alla famiglia delle Ochnaceae, Malpighia, 1901, pp. 105–74 and Tab. v–xi.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 92.—Van Tieghem, Épiblépharide etc., Journ. de bot., 1901, pp. 389–94.—Gerhard, Blattanat. v. Gew. des Knysnawaldes, Diss., Basel, 1902, pp. 8–10 (*Ochna*).—Van Tieghem, Ochnacées, Ann. sc. nat., sér. 8, t. xvi, 1902, pp. 161–416.—Van Tieghem, Deux Ochnacées, Bull. Mus. d'hist. nat., 1902, pp. 47–52.—Van Tieghem, Cristarque etc, Bull. Mus. d'hist. nat., 1902, pp. 266–73.—Van Tieghem, Une Ouratée etc., Bull. Mus. d'hist. nat., 1902, p. 615.—Van Tieghem, Sétouratée, Campylosperme et Bisétaire, Journ. de bot., 1902, pp. 33–47.—Lecomte, Bois du Congo, Bull. Mus. d'hist. nat., 1903, p. 89.—Van Tieghem, Nouv. obs. sur les Ochnacées, Ann. sc. nat., sér. 8, t. xviii, 1903, pp. 1–60.—Van Tieghem, Esp. nouv. des Ochnacées, Bull. Mus. d'hist. nat., 1903, pp. 30, 70 and 156 et seq.—Van Tieghem, Luxembourgiacées, Ann. sc. nat., sér. 8, t. xix, 1904, pp. 1–96.—Van Tieghem, Wallacée, Bull. Mus. d'hist. nat., 1904, pp. 145–50.—Van Tieghem, Faisc. méd. des Godoyées, Journ. de bot., 1904, pp. 53–64.—Van Tieghem, Franges sécrétr., Journ. de bot., 1904, pp. 105–9.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 29–90 (*Ochna*).—[Pilger, in Natürl. Pflanzenfam., Erg.-Heft. II. 1907, pp. 219, 220.]

BURSERACEAE (pp. 190–194).

2. Structure of the Leaf. The following are additional details as to the nature of the hairy covering (Syst. Anat., p. 191). In *Boswellia Carteri*, Birdw. external glands with a short stalk and a bicellular head divided by a vertical wall occur side by side with thick-walled clothing hairs which are either unicellular or uniseriate (Ad. Peter). *Protium serratum*, Engl. has unicellular trichomes, which are sometimes united to form tufts, while peculiar unicellular lanceolate hairs occur in *Canarium zeylanicum* (Stepowski).

3. Structure of the Axis. Bargagli-Petrucci met with silica-bodies in the wood-parenchyma of an undetermined species of *Canarium* from Borneo. In *Boswellia Carteri* the bast-fibres composing the sclerenchymatous ring are septate like the wood-fibres. In *Protium divaricatum* there is a ring of stone-

cells in the primary cortex (Stepowski). The resin-canals in *Boswellia Carteri* are found also at the periphery of the pith (protoxylem).

In *Boswellia Carteri* the cork arises subepidermally. According to Höhnel and Ad. Peter (see also Mohl), the peculiar exfoliation of membranous cork-layers, already (Syst. Anat., p. 193) described for species of *Boswellia* and *Commiphora*, takes its origin from single layers of phelloid-cells of peculiar structure; the inner tangential walls and the adjoining portions of the radial walls are strongly thickened, lignified and silicified, while the remaining parts of the wall are very thin; moreover the silicified portions are rarely smooth, but have delicate ridges running in the vertical direction and occasionally forking. The process of exfoliation does not, however, take place in every layer of phelloid cells, so that unruptured layers of these cells may be met with in the cork.

Literature: Mohl, in Bot. Zeit., 1861, p. 229.—Höhnel, Kork, Sitz.-Ber. Wiener Akad., lxxvi, Abt. 1, 1877, p. 605 etc.—Johannson, Noch wenig bek. Rinden, Diss., Dorpat, 1891, p. 31 et seq.—Jadin, Térébinthacées, Journ. de bot., 1893, p. 382 et seq.—Boergesen og Paulsen, Vegetat. dansk.-vestind. Öer, Bot. Tidsskrift, xxii, 1898-9, pp. 97, 98 (*Bursera gummifera*, L.).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 84.—Bargagli-Petrucci, Concrez. silicee, Malpighia, 1902, p. 23 et seq.; and Legnami, loc. cit., p. 314 et seq. (*Canarium*, *Santiria*).—Poulsen, Luftrødder hos *Canarium commune*, Vidensk. Meddelels. Kjøbenhavn, 1902, pp. 231–5.—Ad. Peter, Anat. d. Veg. Org. von *Boswellia Carteri*, Sitz.-Ber. Wiener Akad., cxii, Abt. 1, 1903, pp. 511–34 and Tab. i–iii; see also Anzeiger d. Akad., 1903, p. 169.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 134–6.—Stepowski, Anat. Untersuch. über die oberird. Veg. Org. der Burseraceen etc., Diss., Bern, 1905, pp. 11–51.—[Boorsma, Aloëholz, Bull. Départ. de l'Agric. aux Indes néerland., vii, 1907, p. 28 et seq. (*Canarium*).]

MELIACEAE (pp. 194–198).

1. To the Review of the Anatomical Features the following newly discovered facts may be added: Unicellular, two-armed hairs are found also in *Epicharis*. Hypoderm is present in the leaf also in certain species of *Aglaia* and *Sandoricum*. Papillae occur on the lower epidermis of the leaf also in *Heynea*.

2. Structure of the Leaf. Hypoderm is found also in *Carapa obovata*, Bl. (according to Areschoug), *Aglaia cambodiana*, Pierre and *Sandoricum indicum*, Cav. (according to Pierre). The latter author states that the lower epidermis in *Heynea trijuga*, Roxb. bears rather long papillae.

The **secretory cells** characteristic of the members of this Order are according to Pierre in some cases surrounded by special cells resembling an epithelium. Mucilage-cells are stated by Areschoug to occur in the palisade-tissue of *Carapa obovata*.

To the section dealing with the **hairy covering** we may add the following information. Simple unicellular clothing hairs are present also in species of *Chisocheton* and *Dysoxylum*, and unicellular two-armed hairs also in *Epicharis Juglans*, Hance, and *E. hoaensis*, Pierre. Glandular hairs, sunk, like those of *Cabralea*, in deep pits, the apertures of which appear as dots on the surface of the leaf, occur also in *Dysoxylum Loureiri*, Pierre (Pierre). According to Areschoug, peculiar hydathodes are found on the lower surface of the leaf in *Carapa obtusa*; they consist of a small-celled tissue situated beneath the epidermis, which subsequently becomes resorbed at these points.

Note. We may add that according to Pitard the fruit-stalks of *Swietenia Mahagoni* and *Aglaia Roxburghii* exhibit polystelic structure. For the detailed structure of the horn-shaped respiratory organs, found in *Carapa moluccensis*, Lam. (and exhibiting a peculiar formation of intercellular spaces in the primary cortex), see Karsten, loc. cit.

Literature: Karsten, Mangroveveget., Bibl. bot., Heft 22, 1891, pp. 51, 52.—[Rusby, Coblentz and Wilcox, Coccillana (*Guarea*), Bull. of Pharm., 1893, p. 350 et seq.]—Pierre, Flore forest. de la

Cochinchine, xxii, 1896, and xxiii, 1897.—[Mitlacher, Meliaceen-Kinden, Zeitschr. allg. österreich. Apotheker-Ver., 1900, p. 573 et seq.; abstr. in Just, 1900, ii, p. 47.]—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 93.—Areschoug, Mangrovevegetat., Bibl. bot., Heft 56, 1902, pp. 46, 47 and Tab. iii–iv.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 316 et seq. (*Carapa*, *Dysoxylum*, *Sandoricum*).—Pitard, Polystélie, Actes Soc. Linn. de Bordeaux, sér. 6, t. vii, 1902.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 98, 99 (*Cipadessa*).—Piccioli, Legnami, Bull. Siena, 1906, pp. 147, 149 and 163.—[For additional literature see p. 1171.]

CHAILLETIACEAE (pp. 198–200).

Literature: C. de Candolle, Inflor. épiphylles, Mém. Soc. de phys. et d'hist. nat. Genève, 1890, vol. supp., sep. copy, p. 14 et seq.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 93.

OLACINEAE (pp. 200–209).

1. Anatomical Features. First, as regards the structure of the leaf, we may add that stomata with subsidiary cells placed parallel to the pore, previously recorded in *Opilia*, are present also in *Coula* and other genera, hypoderm also in species of *Schöpfia*, spicular cells in *Anacalosa puberula*, Kurz, and spicular fibres running freely in the mesophyll in *Minquartia* and *Eganthus*[1]. In the Olacineae recently investigated by Colozza, the wood-prosenchyma also bears bordered pits in all cases. Laticiferous tubes, already recorded in *Endusa* and *Cardiopteris*, are present also in *Coula*, *Eganthus*, *Minquartia* and *Ochanostachys*, whilst schizogenous secretory cavities, besides occurring in *Coula* and *Endusa*, have been observed in *Eganthus*, *Minquartia* and *Ochanostachys*. Amongst noteworthy types of hairs we may mention the branched multicellular trichomes of *Ximenia caffra*, Sond. and the tufted hairs found on the branches of *Coula*, *Ochanostachys* and *Minquartia*.

2. Structure of the Leaf[2]. Van Tieghem states that the leaves in *Coula*, *Ochanostachys* and *Minquartia* have bifacial structure with the stomata on the lower side. According to the same authority the **stomata** are accompanied by subsidiary cells placed parallel to the pore in *Coula edulis*, and according to Pierre in *Anacalosa Clarkii*, Pierre, *Melientha suavis*, Pierre, *Olax imbricata*, Roxb. var. *cambodiana*, Pierre, *Schöpfia fragrans*, Wall. and *S. Miersii*, Pierre, and according to Gerhard in *Apodytes dimidiata*. The two species of *Schöpfia* just named have a hypoderm composed of two layers. According to Colozza, the **mesophyll** in *Heisteria cauliflora*, Sm. and *Anacalosa puberula*, Kurz contains 'sclerenchymatous idioblasts,' while in *Minquartia* and *Eganthus*, according to Van Tieghem, it includes sclerenchymatous fibres, having the same structure as those of *Endusa*.

According to Van Tieghem, three vascular bundles pass out into the leaf in *Coula*, *Minquartia* and *Ochanostachys*; the two lateral bundles branch off from the vascular ring of the axis a little way below the node. According to Pierre, there are likewise three bundles in *Anacalosa*, *Apodytes*, *Erythropalum*, *Olax* and *Strombosia*, while in *Melientha*, *Schöpfia* and *Ximenia* there is only a single bundle. The **petiole**, according to Colozza, contains a stele in *Coula*, *Heisteria*, *Ochanostachys*, *Scorodocarpus* and *Strombosia*, while in *Anacalosa*, *Liriosma*, *Olax* and *Ximenia* the vascular bundles are arranged to form an arc.

A few facts may be taken from the new records of the occurrence of

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[1] Van Tieghem unites *Coula*, *Eganthus*, *Endusa* and *Minquartia* to form a separate Order (Coulaceae).

[2] Colozza's recent investigations on the structure of the leaf deal with the genera *Anacalosa*, *Coula*, *Heisteria*, *Liriosma*, *Ochanostachys*, *Olax*, *Strombosia* and *Ximenia*; Colozza moreover also examined the structure of the axis in these genera, as well as in *Schöpfia*.

secretory organs mentioned above. According to Van Tieghem, the laticiferous tubes found in *Coula, Minquartia, Ochanostachys* and *Eganthus* are branched and unseptate (' non cloisonnées ')[1]; special emphasis is laid on the latter point, at least as far as the three first-named genera are concerned. The laticiferous elements are present in the pith, primary cortex and bast of the branch; in the leaf they are met with especially in the veins. According to Van Tieghem, the secretory cavities occur in the primary cortex of the branch[2] and in the mesophyll; in *Coula, Minquartia* and *Ochanostachys* their contents, as in the case of *Endusa*, assume a blue colour after treatment with Eau de Javelle.

Colozza has published a number of new statements on the mode of deposition of **oxalate of lime** in the axis, the lamina of the leaf and the petiole. Of these we may mention that solitary crystals occur also in *Coula, Liriosma, Ochanostachys, Strombosia* and *Ximenia*, and clustered crystals also in *Anacalosa, Coula, Heisteria* and *Ochanostachys*.

We may lastly mention the special forms of clothing **hairs** that have been recently recorded. Colozza describes the trichomes of *Ximenia caffra* as ' peli pluricellulari, semplici o ramificati,' Van Tieghem those of *Coula*, &c., as ' poils unisériés, ramifiés à la base en forme de bouquet.'

3. Structure of the Axis. The previous account of the structure of the **cortex** needs the following additions. In *Coula, Minquartia* and *Ochanostachys* the development of the cork takes place in the subepidermal layer of cells; in these genera cells with strongly thickened tangential walls are found amongst the thin-walled cells of the cork (Van Tieghem). According to Van Tieghem, the pericycle in the three genera just named contains a composite and continuous ring of sclerenchyma; Colozza describes bands of bast-fibres as present in the pericycle in species of *Liriosma, Olax, Schöpfia* and *Ximenia*, and a ring of sclerenchyma in species of *Anacalosa, Heisteria, Scorodocarpus* and *Strombosia*, while Pitard records isolated groups of bast-fibres in the pericycle of *Heisteria coccinea* and *Olax imbricata* (*Fissilia psittacorum*). Secondary hard bast has been observed in *Liriosma* (Kleesattel).

According to Leisering, the **interxylary phloem** found in *Sarcostigma Kleinii* is given off by the cambium on its outer side, but subsequently becomes bridged over by a cambial arc; in other words, its mode of development is that characteristic of the *Strychnos*-type.

Literature: Wijnaendts Francken, Sklereiden, Diss., Utrecht, 1890, p. 52.—Kleesattel, Muira Puama, Diss., Erlangen, 1892, 44 pp., 2 Tab.—Pierre, Flore forest. de la Cochinchine, xvii, 1892. —Leisering, Interxylaeres Leptom, Diss., Berlin, 1899, p. 17.—Van Tieghem, Deux genres nouv. pour la fam. d. Coulacées. Bull. Mus. d'hist. nat., 1899, pp. 97-100.—Van Tieghem, Coulacées, Journ. de bot., 1899, pp. 69-79; and Ann. sc. nat., sér. 8, t. x, 1899, pp. 125-36.—Heckel, Parasitisme de *Ximenia americana*, Comptes rendus, Paris, cxxxi, 1900, pp. 764, 765.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 84 and 93.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 293 (*Scorodocarpus*).—Gerhard, Blattanat. v. Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 10, 11 (*Apodytes*).—Van Tieghem, Coulacées, Journ. de bot., 1902, p. 225.—Colozza, Anat. delle Olacin., Nuovo Giorn. bot. Ital., xi, 1904, pp. 539-65.

OCTOCNEMACEAE.

We may follow Engler (Natürl. Pflanzenfam., Ergänz.-Heft, i, 1900, p. 19) and Van Tieghem in regarding the genus *Octocnema* as constituting a special Order. *Octocnema* is characterized by the following anatomical

[1] Van Tieghem also describes the laticiferous tubes present in *Endusa* as unseptate, but this is not the case (see Syst. Anat., p. 202); he himself observed the occurrence of anastomoses in this genus.

[2] Colozza's statement that in *Coula* and *Ochanostachys* the secretory cavities occur also in the pith is no doubt incorrect.

features: multicellular tufted or stellate clothing hairs; oxalate of lime in the form of solitary crystals; stomata without subsidiary cells; absence of cortical vascular bundles; a composite and continuous ring of sclerenchyma in the pericycle; occurrence of secondary hard bast; and subepidermal development of cork.

The two species, *O. Klaineana*, Pierre and *O. affinis*, Pierre, have been examined by Van Tieghem. The hairy covering varies somewhat in the two cases, being floccose or tufted in *O. Klaineana*, and composed of stellate hairs having their ray-cells spread out parallel to the surface of the organ in *O. affinis*. The mesophyll is compact on the upper side of the leaf and lacunar towards the lower side; the outer layer of the compact portion contains thick crystals. The stomata are confined to the lower surface of the leaf. The vascular bundles in the lateral veins are accompanied by hard bast and provided with an endodermis containing crystals. Five vascular bundles pass out into the leaf; for the further course of these bundles, which varies slightly in the two species, see Van Tieghem, loc. cit.

As regards the structure of the **axis**, we may first note that the cork, as above mentioned, develops in the subepidermal layer of cells. The cells of the cork are sclerosed on the outer tangential and radial walls. The primary cortex contains stone-cells, which are either thickened uniformly or in the form of a horseshoe; in the latter case they enclose a crystal. The endodermis is not distinctly differentiated, although many of its cells contain crystals. In young branches the pericycle comprises isolated groups of bast-fibres, but in later stages a composite and continuous ring of sclerenchyma is developed. The secondary bast of the thicker branches contains small groups of bast-fibres, which are arranged in several layers and are enveloped by chambered crystal-fibres with solitary crystals. The medullary rays of the wood are uniseriate. Nothing is known as to the structure of the vessels and wood-prosenchyma. The pith includes groups of stone-cells, whilst in its peripheral portion an arc of lignified tissue is situated opposite each group of primary xylem.

Literature: Van Tieghem, Octocnème, Journ. de bot., 1905, pp. 45–58, especially pp. 47–50.

ILICINEAE (pp. 209–211).

2. STRUCTURE OF THE LEAF. Supplementary observations on the structure of the leaf are contained in Cador's work (loc. cit.) and in the literature cited below. In surface-view the **epidermal cells** show straight or undulated lateral margins; in other cases they appear to be undulated at a high focus and straight at a low focus, this feature being combined with the presence of marginal pits. A two-layered epidermis on the upper side of the leaf has been recorded also in *Ilex canariensis*, Poir. and *I. capensis*, whilst in *I. theezans*, Mart. var. *fertilis*, Loes. and var. *Riedelii*, Loes. the epidermis consists locally of two layers; in *I. chamaedryfolia*, Reiss. var. *typica*, Loes. occasional horizontal division-walls are met with in the upper epidermis. A one-layered hypoderm is stated to occur on the upper side of the leaf in *I. platyphylla*, Webb et Berth. Gelatinization often affects almost all the cells of the upper epidermis, while in other cases isolated cells of both upper and lower epidermis exhibit this feature. Gelatinization has been recorded in the following species and varieties: *Ilex affinis*, Gardn. var. *genuina*, Loes. and var. *rivularis*, Loes., *I. amara*, Loes. var. *longifolia*, Loes. and var. *latifolia*, Loes., *I. Caroliniana*, Loes., *I. Cassine*, L. var. *myrtifolia*, Chapm., *I. chamaedryfolia*, Reiss. var. *typica*, Loes., *I. cognata*, Reiss., *I. Congohinha*, Reiss., *I. conocarpa*, Reiss., *I. Cujabensis*, Reiss., *I. dumosa*, Reiss. var. *Guaranina*, Loes., *I. glabra*, Gray, *I. Glazioviana*, Loes., *I. Para-*

guariensis, St. Hil. var. *genuina*, Loes., *I. Pseudothea*, Reiss., *I. symplociformis*, Reiss. In some cases the epidermal cells exhibit a palisade-like elongation in transverse sections of the leaf, e.g. in *I. theezans* var. *fertilis*. The cuticular ridges occasionally form a kind of rampart around the **stomata**; in *I. theezans* var. *typica* the stomata are surmounted by a ridge-like elevation or a chimney-shaped space, as the case may be, due to the neighbouring cells projecting in the form of a ridge. The neighbouring cells of the stomata in some cases bear a slight resemblance to subsidiary cells, e.g. in *I. Paraguariensis*. The **mesophyll** commonly contains fat-bodies. In *I. Cassine* var. *myrtifolia* the two lowest layers of the spongy tissue consist of cells with thick pitted walls; the palisade and spongy tissue in *I. glabra* contains round cells having wide lumina and sclerosed on one side.

An additional feature presented by the **hairy covering** is the occasional occurrence of long, unicellular trichomes. The clustered crystals of **oxalate of lime** are frequently enclosed in relatively large cells, which are differentiated as idioblasts. In *Ilex Cassine* var. *myrtifolia*, *I. dumosa* var. *Guaranina*, and *I. paltarioides*, Reiss., Cador met with sphaerocrystalline masses (hesperidin ?) in the epidermis of the leaf, while in *I. Pseudothea* he observed yellowish crystals of varying size and composed of an unknown chemical substance.

For the distribution of the abundant **cork-warts**, which in certain species cause a punctate appearance on the lower surface of the leaf, see especially Loesener's monograph (in Nova Acta Leopold.-Carol. deutsch. Acad., lxxviii, 1901); regarding the occurrence of domatia and their structure, see Loesener in Biolog. Centralbl., 1893, p. 449 et seq.

3. Structure of the Axis. According to Pitard, a composite and continuous ring of sclerenchyma is present also in *Ilex celastroides* and *Byronia taitensis*.

Literature: Pierre, Flore forest. de la Cochinchine, xviii, 1893.—Loesener, *Ilex paraguariensis*, Notizbl. Berlin, n. 10, 1897, p. 314 et seq.—Cador, Anat. Untersuch. der Matebl., Diss., Erlangen, 39 pp.; sep. copy from Bot. Centralbl., 1900, iv, p. 241 et seq.—Kearny, in Contribut. U. S. Nat. Herb., v, 5, 1901, p. 296.—Petersen, Vedanatomi, 1901, pp. 50, 51.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 72.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 323.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 23-6.—Gerhard, Blattanat. v. Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 11-14[1].—Neger and Vanino, Paraguaythee, 1903, pp. 449-52.—Piccioli, Legnami, Bull. Siena, 1906, p. 136.—[For additional literature see p. 1170.]

CELASTRINEAE (pp. 212-214).

Thanks to the recent investigations of Stenzel and Metz, the structure of the leaf and axis in this Order is now well known. Their work necessitates the following alterations or additions in the GENERAL DIAGNOSIS[2]. The development

[1] The plant which Gerhard describes under the name of '*Ilex Cassini*' (sphalm. ex. '*I. Cassine*'), from specimens growing in the Botanic Gardens at Basel, does not belong to the genus *Ilex*, as is shown by the anatomy of the leaf (spicular cells, peltate glands); except for the statement as to the occurrence of clustered crystals there is nothing against the plant in question being a member of the Oleaceae.

[2] Stenzel's and Metz's investigations extend to the following genera, which are enumerated in the serial order of Loesener's system: *Euonymus*, *Lophopetalum*, **Glyptopetalum*, *Microtropis*, *Denhamia*, *Celastrus*, *Maytenus*, *Gymnosporia*, *Putterlickia*, *Catha*, *Pterocelastrus*, *Polycardia*, *Kurrimia*, *Pachystima*, **Kokoona*, ***Zinowiewia*, *Plenckia*, *Tripterygium*, *Wimmeria*, *Elaeodendron*, *Cassine*, *Mystroxylon*, *Maurocenia*, *Hartogia*, *Pleurostylia*, **Lauridia*, ***Gyminda*, *Myginda*, *Fraunhofera*, *Mortonia*, **Glossopetalum*, *Schaefferia*, **Perrottetia*, *Goupia*, and *Siphonodon*. The genera provided with an * have been investigated by Stenzel only, those marked with ** by Metz only; Stenzel's work deals with the structure of the leaf and axis, whilst that of Metz is concerned only with the structure of the leaf.

of the cork occasionally takes place in a deeply situated cell-layer of the primary cortex. The hairy covering consists of unicellular or uniseriate clothing hairs, the former often being short and differentiated as papillae; hairs are not of common occurrence and are never present in large numbers. Special forms of clothing hairs (such as unicellular one- or two-armed hairs, and forked multicellular trichomes) are very rare. A widely distributed feature is the occurrence of small bodies, consisting of caoutchouc or fat, in the mesophyll. Special features in the structure of the leaf may be briefly enumerated as follows:—palisade-like differentiation of the epidermal cells; papillae on the epidermis (very rare); mucilaginous epidermal cells (very rare); peculiar pit-canals in the outer wall of the epidermal cells (*Mortonia*); hypoderm or an epidermis of several layers; crystal-cells in the epidermis; spicular fibres in the mesophyll. The secretory receptacles are represented by: (*a*) long secretory sacs, which are mostly filled with a substance resembling caoutchouc and capable of being drawn out into threads ('spinning') (*Celastrus, Euonymus, Mystroxylon, Wimmeria*); (*b*) secretory canals (*Mortonia, Pachystima*); and (*c*) tannin-idioblasts. The earlier statement as to the presence of 'resin-cells?' in *Kokoona* has been traced to the occurrence of cork-warts on the lower side of the leaf.

In the STRUCTURE OF THE LEAF the **epidermis** in the first place affords a large number of systematic characters. The size of the epidermal cells, the nature of their lateral margins and the thickness of the outer walls, are features which are subject to variation. Palisade-like elongation of the epidermal cells is found in *Cassine scandens*, Eckl., *Gymnosporia laurina*, Szysz., *Kokoona zeylanica*, Thw., *Maurocenia Frangularia*, Mill., *Mortonia Greggii*, Gray, *Polycardia Hildebrandtii*, Baill., species of *Pterocelastrus*, and *Putterlickia pyracantha*, Endl. Striation of the cuticle is met with in species of *Microtropis, Polycardia* and *Zinowiewia*, especially in the neighbourhood of the stomata. In *Catha edulis*, Forsk. and *Goopia glabra*, Aubl. the outer walls bear linear pits; in *Polycardia Hildebrandtii*, Baill. and *P. libera*, O. Hoffm. they are provided with delicate pits. In *Mortonia Greggii*, Gray the outer walls are traversed by peculiar long pit-canals, which may be either branched or unbranched, and run in all directions, though for the most part parallel to the principal vein; the outer ends of these canals invariably come to lie above the lateral margins. Marginal pits have also been observed in forms having epidermal cells with undulated lateral margins (species of *Cassine, Elaeodendron, Gyminda, Kurrimia, Lauridia*). In some cases (species of *Elaeodendron, Gymnosporia, Maurocenia, Maytenus, Microtropis, Myginda*) the lumina of the epidermal cells are considerably narrowed owing to the thickening of the walls. Mucilaginous epidermal cells have only been recorded in *Goupia glabra*, Aubl., *Perrottetia alpestris*, Loes. and *P. sandwicensis*, Gray. According to Metz, occasional epidermal cells are very commonly drawn out into papillae or short papillose hairs. A typical papillose epidermis is, however, present only in *Wimmeria confusa*, Hemsl. (on the upper side of the leaf) and in *Siphonodon celastrinus*, Griff. (on the lower side of the leaf). In certain species of *Gymnosporia, Catha, Elaeodendron* and *Plenckia* the epidermis consists locally of two or three layers owing to the presence of division-walls parallel to the surface of the leaf, while in *Goupia glabra*, Aubl., *Gymnosporia linearis*, Loes., *G. senegalensis*, Loes. and *G. Wallichiana*, Spreng. the epidermis is typically two- or three-layered. In *Goupia glabra* the horizontal division-walls are accompanied by vertical ones; vertical walls are also present in species of *Euonymus, Gymnosporia, Kurrimia* and *Polycardia*. **Hypoderm** is of frequent occurrence. A continuous hypoderm consisting of one or more layers and situated either only on the upper or on both sides of the leaf has been observed in certain species of *Cassine, Celastrus, Denhamia, Elaeodendron, Gyminda,*

Gymnosporia, Maurocenia, Maytenus, Myginda, Mystroxylon and *Schaefferia* [1]. In other species belonging to these genera, as well as in *Plenckia populnea*, Reiss., the hypoderm is confined to certain parts of the leaf, situated especially in the neighbourhood of the veins. A last feature requiring special mention is the occurrence of **crystal-cells** in the epidermis of the leaf in species of *Catha, Denhamia, Elaeodendron, Euonymus, Gyminda, Kurrimia, Lophopetalum, Maytenus, Microtropis, Myginda, Pleurostylia, Siphonodon*, and *Wimmeria* [2]. In most cases each of the crystal-cells contains a solitary crystal, rarely a clustered crystal. These crystal-cells are found either in both upper and lower epidermis, or only in the lower epidermis, and may be present in large or small numbers. In certain species they differ from the remaining epidermal cells, this being especially the case in the species of *Elaeodendron*. Here the crystal-cells either form rows of as many as twelve cells or groups of two to six cells lying side by side, or are isolated; in the latter case they are surrounded by a kind of rosette formed by the neighbouring cells; the crystal-idioblasts are further frequently rounded and smaller than the other epidermal cells, and may even have thickened inner walls in which the crystals are inserted. *Gyminda* shows similar features to those just described for the species of *Elaeodendron*. In *Siphonodon* the crystal-cells are distinguished from the other epidermal cells by the absence of papillae. In *Lophopetalum* and *Microtropis discolor*, Wall. ordinary cells of the epidermis are divided up into two or three chambers by means of delicate walls, each chamber enclosing a clustered crystal.

The **stomata** are as a rule confined to the lower side of the leaf. They are developed in considerable numbers on the upper side of the leaf, for instance, in species of *Gymnosporia* and *Maytenus*, as well as in *Mortonia*. There is no uniform type of stoma. In most cases the stomata are surrounded by 3, 4 or more neighbouring cells, but in many species some of the stomata are accompanied by subsidiary cells placed parallel to the pore. According to Metz, the Rubiaceous type is well marked in *Kurrimia*; in *Lauridia* there are mostly two pairs of subsidiary cells arranged cross-wise, and in *Mortonia* the pairs of guard-cells are surrounded by a rosette of smaller epidermal cells.

The leaves for the most part show bifacial structure. Distinct centric structure with palisade-tissue situated on both sides of the leaf has been recorded

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[1] The species are: *Cassine barbara*, L., *C. capensis*, L., *C. sphaerophylla*, O. Ktze.; *Celastrus australis*, F. v. M., *C. disperma*, F. v. M., *C. papuana*, Warb.; *Denhamia obscura*, Meissn.; *Elaeodendron australe*, Vent., *E. capensis*, Eckl. et Zeyh., *E. croceum*, DC., *E. glaucum*, Pers., *E. ilicifolium*, Hochst., *E. orientale*, Jacq., *E. papillosum*, Hochst., *E. quadrangulatum*, Reiss., *E. Schweinfurthianum*, Loes., *E. xylocarpum*, DC.; *Gyminda Grisebachii*, Sarg.; *Gymnosporia angularis*, Loes., *G. buxifolia*, Szysz., *G. Cunninghamii*, Loes., *G. lucida*, Loes., *G. procumbens*, Loes., *G. venenata*, Szysz., also *G.* (?) *gracilis*, Pierre and *G. mekongensis*, Pierre, according to Pierre; *Maurocenia Frangularia*, Mill.; *Maytenus obtusifolia*, Mart., *M. phyllanthoides*, Benth., *M. viscifolia*, Griseb., *M. Vitis Idaea*, Griseb.; *Myginda Gaumeri*, Loes., *M. ilicifolia*, Lam., *M. latifolia*, Sw., *M. pallens*, Sm., *M. Rhacoma*, Sw.; *Mystroxylon pubescens*, Eckl., *M. sphaerophyllum*, Eckl. et Zeyh. *β litorale*, Harv. et Sond.; *Schaefferia frutescens*, Jacq.

[2] The species in question are the following: *Catha edulis*, Forsk. (clust. cryst.); *Denhamia obscura*, Meissn.; *Elaeodendron australe*, Vent., *E. capense*, Eckl. et Zeyh., *E. croceum*, DC., *E. glaucum*, Pers. (clust. cryst. or solitary and clust. cryst.), *E. ilicifolium*, Ten., *E. orientale*, Jacq., *E. papillosum*, Hochst., *E. quadrangulatum*, Reiss., *E. Schweinfurthianum*, Loes. (solitary and clust. cryst.), *E. xylocarpum*, DC.; *Euonymus americanus*, L.; *Gyminda Grisebachii*, Sarg.; *Kurrimia* (according to Stenzel); *Lophopetalum fimbriatum*, Wight, *L. Wightianum*, Arn.; *Maytenus acanthophylla*, Reiss., *M. aquifolia*, Mart., *M. basidentata*, Reiss., *M. Catingarum*, Reiss., *M. horrida*, Reiss., *M. ilicifolia*, Mart., *M. laevis*, Reiss., *M. macrophylla*, Mart., *M. Mülleri*, Schwacke, *M. myrsinoides*, Reiss., *M. obtusifolia*, Mart., *M. rigida*, Mart., *M. viscifolia*, Griseb.; *Microtropis bivalvis*, Wall., *M. densiflora*, Wight, *M. discolor*, Wall., *M. latifolia*, Wight, *M. ovalifolia*, Wight; *Myginda Crossopetalum*, L., *M. latifolia*, Sw.; *Pleurostylia Wightii*, Wight et Arn. (acicular crystals); *Siphonodon celastrinus*, Griff. (clust. cryst.); *Wimmeria serrulata*, Radlk. (solitary and clust. cryst.). **Except where there is a special statement to the contrary, only solitary crystals are present.**

in species of *Gymnosporia*, *Maytenus* and *Mortonia*, while the **mesophyll** is homogeneous in species of *Gymnosporia*, *Myginda Gaumeri*, Loes. and *Zinowiewia integerrima*, Turcz. Other noteworthy features are: palisade-cells exhibiting transverse division (in species of *Mortonia* and *Pachystima*); layers of rather strongly thickened cells (in the palisade-tissue in *Elaeodendron Schweinfurthianum*, and in the spongy tissue in *Maurocenia*); and spicular fibres (in species of *Gymnosporia*, *Maurocenia*, *Maytenus*, *Microtropis*, *Pterocelastrus*, and *Schaefferia* [1]). The spicular fibres branch off from the sclerenchyma of the veins and penetrate more or less deeply into the mesophyll; in some cases they extend as far as the epidermis, or may even spread out between the epidermis and the mesophyll. They are rarely present in any considerable numbers.

According to Pierre, the **petiole** is supplied by three vascular bundles in *Kurrimia*, but only by a single bundle in *Celastrus*, *Elaeodendron*, *Euonymus*, *Gymnosporia*, *Microtropis*, *Pleurostylia* and *Siphonodon*. The vascular system of the petiole and midrib is either of a horseshoe form or annular and closed. In the latter case medullary vascular bundles are occasionally (*Goupia*, *Kurrimia*, *Lophopetalum*) found within the vascular ring, and in *Goupia glabra* there is also a cortical bundle situated in each of the two angles of the petiole. The vascular bundles of the **veins** are for the most part accompanied by sclerenchyma. Vertical transcurrence of the smaller veins has been observed in species of *Cassine*, *Plenckia*, *Tripterygium* and *Wimmeria*. Enlarged terminal tracheids are present in species of *Goupia*, *Myginda* and *Schaefferia*, while similar reticulately thickened cells accompany the vascular bundles of the veins in *Polycardia libera*, O. Hoffm.

The description of the structure of the leaf may be followed by a general discussion of the hairy covering, the mode of deposition of oxalate of lime and the secretory organs; these will be taken in the order in which they have been named. The **hairy covering** does not include glandular hairs [2]. The clothing hairs are confined to a relatively small number of genera and only rarely form a dense covering. The most widely distributed type of clothing hairs are short unicellular trichomes (species of *Euonymus*, *Fraunhofera*, *Goupia*, *Mystroxylon*), which are either papillose or of slightly greater length. *Tripterygium* has papillose hairs composed of one or two cells, while in *Fraunhofera* the papilla-like trichomes are accompanied by long hairs, which are either unicellular or multicellular with thin transverse walls. *Myginda* has unicellular one-armed hairs, which in *M. ilicifolia*, Lam. are accompanied by unicellular trichomes with two arms. In *Wimmeria*, lastly, the hairs are tubular multicellular structures connected by numerous transitional forms with unicellular papillose hairs. In *W. microphylla*, Radlk. they are commonly seated on two basal cells, the lower of which bears a spinose process at its upper end; in some cases this process is strongly developed, so that forked hairs result.

Oxalate of lime is deposited in the form of solitary or clustered crystals, and as crystal-sand. The solitary crystals are generally rhombohedral, although sometimes 'very long' (in the palisade-tissue of *Kurrimia*) or 'rod-shaped' (in *Fraunhofera*) or 'hastate or acicular' (in the tissue of the leaf of *Glossopetalum spinescens*, Gray and in numerous species of *Maytenus*). The crystal-sand never occurs independently, but is invariably found together with a solitary

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[1] viz.: *Gymnosporia emarginata*, Roth, *G. laurina*, Saysz., *G. ovata*, Laws., *G. Royleana*, Wall.; *Maurocenia Frangularia*, Mill.; *Maytenus acanthophylla*, Reiss., *M. amazonica*, Mart., *M. laevis*, Reiss.; *Microtropis densiflora*, Wight, *M. discolor*, Wall., *M. latifolia*, Wight, *M. ovalifolia*, Wight, *M. ramiflora*, Wight; *Pterocelastrus variabilis*, Sond. var. *litoralis* and var. *obtusilobus*, *P. rostratus*, Walp.; *Schaefferia frutescens*, Jacq.

[2] Stenzel's statement regarding the occurrence of peltate glands in *Rhacoma microphylla*, Loes. is incorrect. The plant examined by Stenzel does not belong to the Celastrineae, but is probably a member of the Verbenaceae.

or clustered crystal, e.g. in species of *Elaeodendron, Maurocenia, Microtropis, Mortonia, Mystroxylon, Siphonodon*. Within the limits of the same genus the tissues of the leaf and axis in some cases contain either solitary crystals only or clustered crystals only, or the two forms occur side by side. In other genera the forms of crystals found in the leaf and axis are different in the two cases; most commonly the leaf contains clustered crystals only, while the axis includes both solitary and clustered crystals. In *Denhamia, Kurrimia, Lophopetalum* and *Pleurostylia* solitary crystals alone are present in the leaf and axis; with these genera we may class *Fraunhofera* and *Plenckia*, which likewise have solitary crystals only, although in this case the crystals are confined to the leaf. In *Euonymus, Glyptopetalum, Pachystima, Perrottetia* and *Tripterygium* only clustered crystals are found in the leaf and axis; in *Goupia* also only clustered crystals have been recorded, but they are only present in the leaf. Finally, solitary and clustered crystals occur side by side in both stem and leaf in *Cassine, Elaeodendron* and *Maurocenia*. The occurrence of oxalate of lime in the epidermis has already been dealt with above. Other features requiring mention are: the occurrence of relatively large crystal-idioblasts in the mesophyll (species of *Cassine, Catha, Celastrus, Euonymus*, &c.); septate palisade-cells, the chambers of which contain crystals (*Elaeodendron capense*, Vent., *Mortonia Greggii*, Gray); cells with unilateral or uniform thickening, which contain solitary crystals, and are found in contact with the epidermis on both sides of the leaf (*Kurrimia*); the occurrence of complete layers of crystal-cells in the mesophyll (*Pleurostylia Heynei*, W. et A., *Pterocelastrus tricuspidatus*, Sond.).

Among the **secretory organs** we may first discuss the long secretory sacs occurring in species of *Celastrus, Euonymus* and *Wimmeria*, as well as in *Mystroxylon eucleaeforme*, Eckl. et Zeyh. In *Celastrus* (*C. acuminatus*, L. f.) they were met with by Gerhard in the veins of the leaf (in the pericycle). In *Euonymus* (*E. alala*, Thunb., *E. americanus*, L.[1], *E. atropurpureus*, Jacq., *E. europaeus*, L., *E. japonicus*, Thunb., *E. latifolius*, L., *E. verrucosus*, Scop.), according to Col, they are confined to the bast of the stem and root and are not found in the leaf; the secretory sacs of the stem are distinguished by their late appearance, so that they are not met with in the young branches. In *Wimmeria* they were first observed by Radlkofer in the bast of the axis and the veins of the leaf. Metz publishes further details as to their distribution in the leaf. According to him the secretory sacs are for the most part restricted to the veins and occur in the position usually occupied by the hard bast. They are found exclusively at these points in *W. confusa*, Hemsl., *W. microphylla*, Radlk., *W. persicifolia*, Radlk., *W. pubescens*, Radlk. and *W. serrulata*, Radlk., while in *W. concolor*, Cham. et Schlecht., *W. cyclocarpa*, Radlk. and *W. discolor*, Cham. et Schlecht. they also run freely in the palisade and spongy tissues. The secretory sacs of *Mystroxylon eucleaeforme* show a distribution similar to that recorded in *Wimmeria concolor*, &c. In nearly all the species (excepting *Wimmeria pubescens*) the contents of these secretory sacs are of the nature of caoutchouc, and are drawn out in the form of threads ('spinning'), when organs containing large numbers of the sacs are broken in two. The secretory canals of *Mortonia Greggii*, Gray run at the sides of the veins and are found especially within the induplicate margins of the leaves; the solid yellowish contents are soluble in alcohol and Eau de Javelle. Similar secretory canals, which, however, had no contents, have been observed within the duplicate margins of the leaves in *Pachystima Canbyi*, Gray and *P. Myrsinites*, Raf. Metz mentions the

[1] The 'metamorphosed fibres' of *Euonymus obovatus*, Nutt. (= *E. americanus*), mentioned by Möller, are identical with the caoutchouc-sacs above discussed.

occurrence of tannin-idioblasts in the mesophyll in certain species of *Cassine*, *Euonymus*, *Maytenus*, *Microtropis*, *Myginda*, *Pachystima*, *Siphonodon*, *Wimmeria* and *Zinowiewia*; these elements are distinguished from the surrounding cells by their size or shape, and in some cases also by the thickening of the wall.

STRUCTURE OF THE AXIS. The following facts may be added to the section dealing with the structure of the **wood** (Syst. Anat., p. 213) on the basis of Stenzel's work. The diameter of the vessels varies from ·013 (*Glossopetalum*) to ·084 mm. (*Goupia*). Exclusively scalariform perforations, previously recorded in *Elaeodendron*, *Goupia* and *Kurrimia*, are found also in *Perrottetia* (with 30–40 bars); as in the case of *Elaeodendron glaucum*, the scalariform perforations found in *Glossopetalum spinescens*, Gray are confined to the neighbourhood of the primary wood. The type of perforation in the vessels has recently been employed by Loesener as a distinguishing character between *Elaeodendron* (with scalariform perforations, rarely accompanied by simple ones) and *Cassine* (with exclusively simple perforations). Spiral thickening of the walls of the vessels is found also in certain species of *Euonymus*, *Maytenus*, *Mortonia*, *Pachystima* and *Tripterygium*[1]. Apart from the species of *Microtropis*, wood-parenchyma is present in considerable amount also in species of *Cassine*, *Goupia*, *Hartogia*, *Kurrimia* and *Perrottetia*.

Stenzel's investigations on the structure of the **cortex** have afforded the following results. In most of the genera[2] the cork develops in the subepidermal layer of cells, but it arises in the epidermis in *Euonymus*, in the second cell-layer of the primary cortex in *Elaeodendron*, in the third in *Lauridia*, and in a still deeper layer in *Myginda* and *Tripterygium*. The cells of the cork are generally tabular, and for the most part have thin walls; cork-cells exhibiting one-sided sclerosis (viz. on the inner tangential walls) are found also in species of *Elaeodendron*, *Kurrimia* and *Maytenus*. The mechanical elements of the cortex are represented by bast-fibres and stone-cells, but in some cases (*Pachystima Myrsinites*, Raf., *Tripterygium Wilfordi*, Hook. f., *Wimmeria discolor*, Cham. et Schlecht.) they are altogether absent. The pericycle very often contains isolated groups of bast-fibres or an interrupted ring of fibres, while in *Fraunhofera multiflora*, Mart., *Maurocenia Frangularia*, Mill., &c., it includes a composite and continuous ring of sclerenchyma. Stenzel particularly mentions the occurrence of secondary hard bast in *Denhamia obscura*, Meissn.

According to Stenzel, the **pith** is homogeneous in most of the Celastrineae. A heterogeneous pith is present only in a few genera, such as *Lophopetalum*, *Microtropis*, *Perrottetia*, *Polycardia*, and *Pterocelastrus*, while in *Gymnosporia*, for example, the pith may be homogeneous or heterogeneous; *Tripterygium Wilfordi* has an empty pith. Groups of stone-cells are found in the pith in many species of *Maytenus* and in *Kokoona zeylanica*, Thw. Regarding the formation of peculiar cavities (initiated amongst cells containing clustered crystals) in the pith of *Euonymus europaeus*, see Kassner, loc. cit.

Literature: Kassner, Mark einig. Holzpfl., Diss., Basel, 1884, pp. 19–21.—Nanke, Dikotyle Holzpfl., Diss., Königsberg, 1886, p. 6.—Gregory, Cork-wings, Bot. Gazette, 1888, pp. 312–16 (*Euonymus*).—C. de Candolle, Inflor. épiphylles, Mém. Soc. de phys. et d'hist. nat. Genève, 1890, suppl. vol., sep. copy, p. 18 et seq.—Pierre, Flore forest. de la Cochinchine, xix, 1893.—Stenzel, Anat. d. Laubbl. u. Stämme der Celastr. u. Hippocrateaceae, Diss., Erlangen, without date, communicated

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[1] viz.: *Euonymus alata*, Koch, *E. angustifolia*, Vill., *E. atropurpurea*, Jacq., *E. fimbriata*, Wall., *E. garcinioides*, Roxb., *E. japonica*, Thunb., *E. latifolia*, Scop., *E. nana*, Bieb., *E. occidentalis*, Nutt., *E. pauciflora*, Maxim., *E. pendula*, Wall., *E. velutina*, F. et M., *E. verrucosa*, Scop.; *Maytenus ilicifolia*, Mart.; *Mortonia Greggii*, Gray, *M. scabrella*, Gray; *Pachystima Myrsinites*, Raf.; *Tripterygium Wilfordi*, Hook. f.

[2] These genera are: *Cassine*, *Catha*, *Celastrus*, *Denhamia*, *Fraunhofera*, *Goupia*, *Gymnosporia*, *Hartogia*, *Kokoona*, *Kurrimia*, *Lophopetalum*, *Maytenus*, *Microtropis*, *Mortonia*, *Pachystima*, *Plenckia*, *Pleurostylia*, *Polycardia*, *Pterocelastrus*, *Putterlickia*, *Schaefferia*, *Wimmeria*.

to the university of Erlangen in 1892–3, 91 pp.—Loesener, in Engler and Prantl, Nachtr. z. Teil iii–iv, 1897, p. 223.—Boergesen og Paulsen, Veget. dansk.-vestind. Oer, Bot. Tidsskrift, xxii, 1898–9, pp. 98 (*Myginda pallens*, Sm.) and 101 (*Elaeodendron xylocarpum*, DC.).—Beitter, *Catha edulis*, Diss., Strassburg, 1900, pp. 40–3.—Col, Lacticifères à contenu spécial dans les Fusains, Comptes rendus, Paris, cxxxii, 1901, pp. 1354–6.—Petersen, Vedanatomi, 1901, p. 49.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 38.—Bouygues, Pétiole, Thèse, Paris, 1902, p. 16.—Gerhard, Blattanat. v. Gew. des Knysnawaldes, Diss., Basel, 1902, pp. 14–20 (*Celastrus*, *Elaeodendron*, *Pterocelastrus*).—Metz, Anat. d. Laubbl. d. Celastrineen etc., Diss., Erlangen, 1903, 78 pp.; sep. copy from Beih. z. bot. Centralbl., xv.—Süssenguth, Behnarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 25.—Théorin, Växttrichom., Arkiv f. Bot., iii, 1904, p. 5.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 131–3 (*Celastrus*).—Piccioli, Legnami, Bull. Siena, 1906, p. 166.—[Hollendonner, Kork einiger *Evonymus*-Arten, Novl. Közl. Beibl., vi, 1907, pp. [1]–[3].]

HIPPOCRATEACEAE (pp. 214–217).

The necessity for a detailed investigation of the anatomical features in this Order induced F. E. Fritsch to undertake work in this direction. The following statements are based on his paper as well as on Stenzel's dissertation, with which I only became familiar after the publication of the main portion of this book.

The CHARACTERS mentioned (on p. 214) as common to the Hippocrateaceae as the result of a preliminary investigation of *Hippocratea* and *Salacia* have on the whole been proved to be of general application, and apply also to the genus *Campylostemon*. According to Fritsch, however, a composite and continuous ring of sclerenchyma occurs in the pericycle in certain species of *Hippocratea* and *Salacia*, and the development of the cork may take place in deeper cell-layers of the primary cortex. A new ordinal character mentioned by Fritsch is the frequent occurrence of small caoutchouc-bodies in the cells of the mesophyll, these bodies being either soluble or insoluble in ether. According to Fritsch, hypoderm occurs also in *Salacia* and *Campylostemon*, while crystal-cells are met with in the epidermis of the leaf in *Salacia* as well. The caoutchouc-tubes are found in species of *Hippocratea* and *Salacia*; tannin-sacs are present in the bast in species of the same two genera, while special tannin-idioblasts are met with in the mesophyll in species of *Hippocratea* only. Special anatomical features occurring in certain species are as follows:—characteristic unicellular papillose hairs (*Hippocratea aspera*, Lam.); stellate hairs with uniseriate rays (*H. velutina*, Afz.); uniseriate hairs, some of which have a peculiar basal portion with transverse, closely placed septa (*H. iotricha*, Loes.); pitting of the outer walls of the upper epidermal cells of the leaf (*Salacia oblonga*, Wight); branched or unbranched sclerosed cells belonging to the mesophyll, or in other cases spicular fibres connected with the sclerenchyma of the veins (species of *Salacia*); mucilage-cells in the mesophyll (*Hippocratea velutina*, Afz.); cork-warts on the lower side of the leaf (besides occurring in *Salacia attenuata*, Peyr., also in *S. obovata*, Peyr.).

STRUCTURE OF THE LEAF. The epidermal cells of the leaf exhibit diverse features as regards their shape when seen in surface-view, their height, the size of their lumina, and the nature of the inner and outer walls: for information on these points Fritsch's paper must be referred to. The absence of gelatinization in the epidermis and the scarcity of markings on the cuticle (striation in a few species of *Salacia*) are noteworthy features. The presence of pits in the outer walls in *S. oblonga* and the occurrence of cork-warts have already been mentioned above. The crystal-cells found in the epidermis[1], and likewise

[1] Fritsch gives the following synopsis of the occurrence of crystals in the epidermis:—(1) Crystals in ordinary epidermal cells: (*a*) Solitary crystals: *Hippocratea aspera*, Lam., *H. bipindensis*, Loes., *H. micrantha*, Camb., *H. obtusifolia*, Roxb. var. *barbata*, Benth., *H. velutina*, Afz.; *Salacia Kraussii*, Hochst., *S. Staudtiana*, Loes. (*b*) Clustered crystals: *Hippocratea fuscescens*, Kurz,

referred to in the preceding paragraph, contain solitary or clustered crystals. They are either ordinary epidermal cells or are distinguished, not only by their contents, but also betray their differentiation as idioblasts by their shape or small size, or in some cases by stronger thickening of the inner walls. In the genus *Hippocratea*, in which by far the larger numbers of species possess these crystal-cells (exceptions : *H. Bojeri*, Tul., *H. ovata*, Lam., *H. pachnocarpa*, Loes., *H. scandens*, Jacq.), they are very commonly found in groups of two or more, while in *Salacia* they are mostly isolated. Before leaving this subject we may mention the occurrence of 'acicular crystals in the epidermal cells' in *Salacia cognata*, Peyr. and *S. Martiana*, Peyr. **Hypoderm**[1] as a rule is present only on the upper side of the leaf and is specially widely distributed in the genus *Hippocratea*. It consists of one or two layers ; the walls of the hypodermal cells vary in thickness, and the cells themselves may be larger or smaller than the epidermal cells. The **stomata** are generally confined to the lower side of the leaf (exceptions : *Hippocratea celastroides*, H. B. K., *H. tenuiflora*, Mart., *Campylostemon Warneckeanum*, Loes.). As a rule they have no special neighbouring cells, but in exceptional cases, namely in certain species of *Hippocratea*, and especially of *Salacia*, as well as in *Campylostemon*, subsidiary cells occur. In most of these cases the pairs of guard-cells are surrounded by one or rarely (*Salacia dulcis*, Benth.) two rings of four cells of which two are placed parallel to the pore ; the latter are occasionally very narrow and are divided by walls, which are parallel to the pore, or even at right angles to it. The **mesophyll** is generally bifacial in structure ; it is subcentric only in a few species of *Hippocratea* and *Salacia*. Regarding the sclerenchymatous elements found in the mesophyll the following facts may be mentioned. In their simplest form they appear as enlarged and pitted cells of the mesophyll, which do not show any striking difference in shape (*Salacia attenuata*, Peyr., *S. fluminensis*, Peyr., *S. laevigata*, DC., *S. silvestris*, Walp.). With these we may associate branched spicular cells, which are not connected with the sclerenchyma of the vascular system (*Salacia dulcis*, Benth., *S. lacunosa*, Peyr., *S. laevigata*, DC., *S. obovata*, Peyr.), and spicular fibres (*S. amygdalina*, Peyr., *S. crassifolia*, Peyr., *S. elliptica*, Peyr., *S. glomerata*, Peyr., *S. grandiflora*, Peyr., *S. grandifolia*, Peyr., *S. pachyphylla*, Peyr.), which branch off from the sclerenchyma of the veins, traverse the mesophyll in all directions, and frequently form such a dense plexus beneath the epidermis that a kind of hypoderm results. The small **veins** of the leaf are embedded in the mesophyll. There is usually no development of sclerenchyma in the veins. A **hairy covering** is rare among the Hippocrateaceae, and has only been demonstrated in a few species of *Hippocratea*. The extremely small papillose hairs of *H. aspera*, Lam. (?) are conical in shape, and have only a small lumen, which is compressed into the lower portion of the trichome ;

H. Grahami, Wight, *H. indica*, Willd. ; *Salacia dulcis*, Benth., *S. gabunensis*, Loes., *S. laevigata*, DC., *S. Roxburghii*, Wall., *S. tortuosa*, Griff., *S. verrucosa*, Wight. (2) Crystals in special crystal-cells : (*a*) Solitary crystals : *Hippocratea campestris*, Peyr., *H. celastroides*, H. B. K., *H. flaccida*, Peyr., *H. Grisebachii*, Loes., *H. inundata*, Mart., *H. tenuiflora*, Mart., *H. Warmingii*, Peyr., *H. Welwitschii*, Engl. (according to Fritsch, p. 52, whilst on p. 66 he speaks of clustered crystals) ; *Salacia Zeyheri*, Spreng. (*b*) Clustered crystals : *Hippocratea arborea*, Roxb., *H. excelsa*, H. B. K., *H. indica*, Willd., *H. iotricha*, Loes., *H. obtusifolia*, Roxb., *H. Schimperiana*, Hochst. ; *Salacia flavescens*, Kurz, *S. floribunda*, W. et A. var. *densiflora*, Wall., *S. gabunensis*, Loes. It may be added that Stenzel also records solitary crystals in the epidermis in *Hippocratea floribunda*, Benth. and *H. verrucosa*, Griseb.

[1] A hypoderm occurs in : *Hippocratea arborea*, Roxb., *H. aspera*, Lam., *H. Bojeri*, Tul., *H. celastroides*, H. B. K., *H. excelsa*, H. B. K., *H. flaccida*, Peyr., *H. Grahami*, Wight, *H. Grisebachii*, Loes., *H. inundata*, Mart., *H. obtusifolia*, Roxb. var., *H. ovata*, Lam., *H. pachnocarpa*, Loes., *H. scandens*, Jacq., *H. velutina*, Afz., *H. verrucosa*, Griseb., *H. Warmingii*, Peyr., *H. Welwitschii*, Engl. ; according to Pierre also in *H. cambodiana*, Pierre, *H. Chessiana*, Pierre, *H. dinhensis*, Pierre ; further, *Salacia Regeliana*, F. Br. et K. Sch., *S. Zeyheri*, Spreng. ; *Campylostemon Warneckeanum*, Loes.

they are silicified and are the cause of the rough surface of the leaf. In addition to the stellate hairs described above, *H. velutina*, Afz. possesses simple uniseriate trichomes, corresponding in structure to the rays of the stellate hairs. The uniseriate hairs found in *H. iotricha*, Loes. are characterized by the fact that their basal portion, which is sunk in the epidermis, is divided by numerous transverse walls, following very closely upon one another; the lower part of the free body of the hair likewise consists of short cells.

Among the **secretory organs** the caoutchouc-tubes in particular require discussion. Fritsch has investigated the details of their distribution and the exact nature of their contents. They are found both in species of *Hippocratea* and *Salacia*, and in *Campylostemon Warneckeanum*. In some of the species [1] they have been observed only in the axis, while in others [2] they are present both in the axis and in the leaf. The caoutchouc-tubes of the axis are generally situated in the soft bast and pericycle; in the latter case they are sometimes surrounded by hard bast. In *Salacia Regeliana* they are also found in the interxylary phloem. They are rarely (*S. obovata* and *S. serrata*) present in the primary cortex. In the leaf the caoutchouc-tubes are found mainly in the soft bast of the veins or in connexion with the bast, viz. either in the immediate neighbourhood of the hard bast or between the cells of the latter, often taking their place. In most of the species (all those named except *Hippocratea pachnocarpa* and *Salacia micrantha*) the caoutchouc-tubes accompanying the veins send out branches into the mesophyll. On the grounds of an investigation of the embryo of *Hippocratea ovata* Fritsch regards the caoutchouc-tubes of the Hippocrateaceae as being of the nature of laticiferous cells. They have thin walls and a small diameter and are branched, but do not anastomose. Their bright, doubly refracting contents are constituted by threads of caoutchouc, which produce the phenomenon of 'spinning' when the organs containing these caoutchouc-tubes are broken in two; the two ruptured surfaces are then seen to be connected by delicate elastic threads of caoutchouc, which are capable of considerable extension. In concluding the discussion of the long caoutchouc-tubes we may note that rows of shorter cells containing caoutchouc are found in No. 347 b, as well as in Nos. 519 and 632 of H. Schenck's collection of stems; according to Fritsch these stems certainly belong to members of the Hippocrateaceae. The occurrence of mucilage-cells in the mesophyll has already been referred to above. According to Fritsch the tannin-sacs first noticed by me in *Salacia grandifolia*, Peyr. are widely distributed in the Order; they are situated in the neighbourhood of the pericyclic hard bast or in the secondary soft bast; the longest sacs of this kind were observed by Fritsch in *Salacia micrantha*, Peyr. Finally we may point out that in the leaves of certain species of *Hippocratea* the tannin is localized in certain layers of the mesophyll or is confined to the spongy tissue (*H. Bojeri*, Tul., *H. indica*, Willd., *H. obtusifolia*, Willd. var. *barbata*, Benth., *H. Schimperiana*, Hochst., *H. Warmingii*, Peyr., *H. Welwitschii*, Engl.).

The vascular system of the **petiole** shows varying differentiation. It consists either of a horseshoe-like group of vascular bundles (e.g. in *Hippocratea ovata*, Lam. or *Salacia Calypso*, DC.), or of a ring of bundles enclosing an inversely orientated medullary plate of wood and bast (e.g. in *S. micrantha*, Peyr.), or of a flattened ring of bundles with 3–4 inversely orientated cortical bundles on its upper side (e.g. in *S. crassifolia*, Peyr.).

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[1] viz.: *Hippocratea aspera*, Lam., *H. obtusifolia*, Roxb., *H. Warmingii*, Peyr.; *Salacia attenuata*, Peyr., *S. fluminensis*, Peyr., *S. prinoides*, Jack, *S. tortuosa*, Griff.

[2] viz.: *Hippocratea ovata*, Lam., *H. pachnocarpa*, Loes.; *Campylostemon Warneckeanum*, Loes.; *Salacia anomala*, Peyr., *S. Calypso*, DC., *S. Kraussii*, Hochst., *S. macrocarpa*, Welw., *S. micrantha*, Peyr., *S. obovata*, Peyr., *S. Regeliana*, F. Br. et K. Sch., *S. serrata*, Camb.

Structure of the Axis. With reference to the structure of the **wood** the following information may be added. The vessels lie isolated or in pairs in a transverse section of the branch; their diameter may be as much as ·11–·16 mm. in thick stems. Wood-parenchyma is as a rule found only in the neighbourhood of the vessels.

According to Fritsch and Stenzel the cork occasionally develops in the second layer of cells of the primary **cortex**, and according to Stenzel even in the third or fourth layers. The cells of the cork have rather wide lumina; their walls are either thin or exhibit uniform or unilateral thickening, the latter affecting the inner or rarely the outer tangential walls. According to Fritsch, the pericycle in *Campylostemon*, and in some of the species of *Hippocratea* and *Salacia*, contains isolated groups of bast-fibres, which are more or less approximated to one another; in the remaining species of *Hippocratea* and *Salacia* there is a composite and continuous ring of sclerenchyma. The primary cortex frequently includes branched stone-cells, especially in its inner portion. In many species the secondary cortex contains hard bast-fibres, and branched sclerenchymatous cells also occur, e.g. in *Hippocratea pachnocarpa*, Loes. or *Salacia obovata*, Peyr. A specially noteworthy feature is found in the penetration of sclerosed tissue belonging to the medullary rays of the cortex into the medullary rays of the wood in *Hippocratea Bojeri*, Tul.; hand in hand with this goes a sinuation of the edge of the cambium, the convexities of which are directed towards the pith.

The **pith** in some cases (*Hippocratca pachnocarpa*, Loes., *Salacia micrantha*, Peyr.) contains stone-cells.

Literature: Stenzel, Anat. d. Laubbl. u. Stamme d. Celastraceae u. Hippocrateaceae, Diss. Erlangen, 1892–3, especially pp. 84–8.—Pierre, Flore forest. de la Cochinchine, xix, 1893.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, p. 11.—F. E. Fritsch, Vork. v. Kautschuk bei den Hippocrateaceen, verb. mit einer anat.-syst. Unters. etc., Diss., München, 1901, 80 pp., 1 Tab. (sep. copy from Beih. z. bot. Centralbl., xi).—Haberlandt, Sinnesorgane, 1901, p. 134.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 39.—F. E. Fritsch, Caoutchouc in plants, New Phytologist, ii, 1903, pp. 25–30.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 91, 92 (*Salacia*).

PENTAPHYLACACEAE.

The monotypic genus *Pentaphylax* (with *P. euryoides*, Gardn. et Champ.), which is referred to the Ternstroemiaceae by Bentham and Hooker, has recently been regarded as the type of an independent Order hy Engler and Van Tieghem; according to the former it has affinities with the Coriarieae, while Van Tieghem places it near the Celastrineae. *Pentaphylax* exhibits the following anatomical features:—simple, unicellular clothing hairs; mucilage-cells in the primary cortex; deposition of oxalate of lime in the form of solitary and clustered crystals; a composite and continuous ring of sclerenchyma in the pericycle; and subepidermal cork-development.

The following facts may be mentioned regarding the Structure of the Leaf. The leaves are bifacial and have a gelatinized epidermis. The mesophyll contains solitary crystals. Stomata are found only on the lower side of the leaf. A single large arc-shaped vascular bundle passes out into the leaf. The vascular bundles of the veins are provided with a sheath of sclerenchyma.

Structure of the Axis. The cork consists of cells with thin walls. The primary cortex contains relatively large cells, which have thin walls and hyaline mucilaginous contents, and are either isolated or combined to form groups. The endodermis is not distinctly differentiated, but each of its cells contains a solitary crystal. In young branches the pericycle is formed by a ring of fibres, which subsequently becomes replaced by a composite and continuous ring of sclerenchyma. There is no secondary hard bast. Oxalate of

lime occurs in the form of solitary crystals in the soft bast and in the form of clustered crystals in the lignified pith and in the medullary rays of the bast. In thicker branches sclerosed cells are also present in the primary cortex and in the medullary rays of the bast.

Literature: Van Tieghem, Pentaphylace et Corynocarpe, Journ. de bot., 1900, pp. 188–93.

CORYNOCARPACEAE.

This Order, which is referred to the Sapindales by Engler, and is placed near the Geraniales by Van Tieghem, consists only of the genus *Corynocarpus* with *C. laevigatus*, Forst. and *C. similis*, Hemsl.; the anatomy of the first of these species has been investigated. The special anatomical characters of this species are: absence of secretory receptacles; stomata of the Rubiaceous type; vessels with simple perforations; wood-prosenchyma bearing simple pits; subepidermal development of the cork; isolated groups of bast-fibres in the pericycle; clustered and solitary crystals of oxalate of lime.

STRUCTURE OF THE LEAF. The leaf is bifacial in structure. The mesophyll contains clustered crystals. A hypoderm composed of one or two layers is found on the upper side of the leaf, while the lowest layer of the spongy tissue is differentiated so as to resemble a hypoderm. The stomata are confined to the lower epidermis and are bordered by two subsidiary cells placed parallel to the pore. Three vascular bundles pass out into the leaf; of these the median one divides into five bundles, which form an arc open on its upper side.

STRUCTURE OF THE AXIS. The cork consists of cells with thin walls and develops in the second cell-layer of the primary cortex. Phelloderm is present and, like the primary cortex, contains clustered crystals and in later stages sclerosed cells as well. The endodermis is not distinctly differentiated. At the inner ends of the vascular bundles, which are separated by broad medullary rays, there are strands of fibres analogous to the groups of pericyclic bast-fibres and corresponding in position to them. The medullary rays of the bast contain clustered crystals, while those of the wood have large solitary crystals. There is no secondary hard bast. The main mass of the wood is composed of fibres, which may either have thick or thin walls. The pith, the peripheral portion of which becomes lignified in later stages, also contains clustered crystals.

Literature: Engler, Corynocarpaceae, in Nachtr. z. ii–iv. Teil der Natürl. Pflanzenfam., 1897, p. 216.—Van Tieghem, Pentaphylace et Corynocarpe, Journ. de bot., 1900, pp. 193–7.—Hemsley, *Corynocarpus*, Ann. of bot., xvii, 1903, pp. 748–51, and xviii, 1904, pp. 179, 180.

STACKHOUSIEAE (pp. 217, 218).

The anatomy of the two genera *Stackhousia* and *Macgregoria* has recently been subjected to a careful examination by Pampanini and Bargagli-Petrucci [1] in the course of a monographic revision of the Order.

The following anatomical features constitute important DIAGNOSTIC CHARACTERS OF THE ORDER:—the absence of a special type of stoma and of external glands; the occurrence of unicellular clothing hairs and of tannin-cells, which in some cases are differentiated as idioblasts; the simple perforations in the vessels; the fact that part at least of the wood-prosenchyma is provided with bordered pits; the absence of medullary rays in the wood; the almost universal occurrence of bundles of fibres in the outer part of the primary cortex; and lastly, the absence of oxalate of lime.

[1] Bull. de l'Herbier Boissier, 1905, pp. 1156–60; and 1906, pp. 39–44, and tab. xii–xv.

Dealing first with the **stem**, we may note that the above-mentioned bundles of fibres correspond with the ribs on the surface of the stem; the bundles vary in the extent of their development, and are separated from the epidermis by a hypodermal layer of cells; the fibres themselves have a polygonal outline in transverse section, and are for the most part strongly thickened and abundantly pitted. Such strands of fibres have been recorded in all the species of *Stackhousia* except *S. pulvinaris*, as well as in *Macgregoria*. The primary cortex shows varying differentiation, and contains palisade-tissue which is most prominently developed in *Stackhousia aspericocca* var. *incrassata* and *S. Dielsi*. The endodermis is occasionally composed of large cells. In the majority of the species of *Stackhousia* the pericycle contains isolated bundles of fibres; in *Macgregoria* there are likewise small groups of fibres. Pericyclic sclerenchyma is wanting only in *Stackhousia Maideni* and *S. pulvinaris*; in these species, however, there is a suberized endodermis instead. According to Pampanini and Bargagli-Petrucci, the xylem in both genera consists of (*a*) vessels with simple perforations, (*b*) a small amount of wood-parenchyma, and (*c*) wood-prosenchyma bearing bordered pits, medullary rays being absent. The pith is composed of large cells with thin walls.

The structure of the **leaf** is either bifacial or centric; the stomata are found on both sides. The vascular bundles of the veins are not provided with sclerenchyma. In *Stackhousia Brunonis* and *S. pulvinaris* large tannin-cells occur in the primary cortex, and in *S. Brunonis* they are present in the mesophyll as well; in other species of *Stackhousia* (e.g. *S. Hügelii*) and in *Macgregoria racemigera* the tannin-cells found in the primary cortex scarcely differ from the cells of the surrounding tissue. The caoutchouc-bodies, observed by the two authors above named in the cortical parenchyma and the tissue of the leaf, are no doubt of the nature of fat-bodies.

RHAMNEAE (pp. 218–221).

The structure of the leaf is now well known owing to the recent researches of Gemoll and Herzog[1]. No new anatomical features common to all the members of the Order have come to light, but for the purposes of special diagnosis numerous characters have been recognized. The enumeration of special features may be supplemented by the following statements. Secretory cavities, provided with a papillose epithelium, besides occurring in *Karwinskia* are found also in *Rhamnidium* and *Reynosia reticulata*, Urb. Secretory canals with resinous contents and an epithelium resembling that of the secretory cavities in *Karwinskia* are present in the veins of the leaf in *Reynosia revoluta*, Urb. The palisade-tissue in some cases contains isolated enlarged cells filled with mucilage (species of *Condalia*) or tannin (species of *Condalia, Phyllogeiton*, and *Scutia*; also in species of *Maesopsis, Pomaderris* and *Rhamnella*, the cells in question being more or less sclerosed in these three genera) or both mucilage and tannin (species of *Discaria* and *Talguenea*). In *Zizyphus celtidifolius*, DC. (incl. *Z. timoriensis*, DC.) a middle layer of the leaf consists of large mucilage-

[1] These investigations deal with the following genera, which are enumerated in the serial order of Weberbauer's system (in Engler and Prantl, Natürl. Pflanzenfam., iii, 5):—Ventilagineae: *Ventilago, Smythea*; Zizypheae: *Paliurus, Zizyphus, Condalia, Microrhamnus, Krugiodendron, Reynosia, Sarcomphalus, Rhamnidium, Karwinskia, Berchemia, Phyllogeiton* (regarded as a section of *Berchemia* in Weberbauer's system), *Maesopsis, Lamellisepalum, Rhamnella, Dallachya*; Rhamneae: *Sageretia, Scutia, Rhamnus, Hovenia, Ceanothus, Emmenospermum, Noltea, Colubrina, Cormonema, Phylica, Lasiodiscus, Alphitonia, Pomaderris, Trymalium, Spyridium, Cryptandra*; Colletieae: *Talguenea, Trevoa, Discaria, Colletia*; Gouanieae: *Gouania, Reissekia, Helinus, Crumenaria, Marlothia*.

cells, while in *Microrhamnus* the upper layer of the hypoderm is gelatinized. Hypoderm and development of papillae are rare features in the Rhamneae. The spicular cells which Blenk mentions correspond to the sclerosed tanniniferous idioblasts in the palisade-tissue (see above). True glandular hairs are not met with on the surface of the leaf. The following forms of clothing hairs are worthy of special note :—trichomes, in which the body of the hair is unicellular and two-armed, and is seated on an epidermal cell (*Sageretia*) ; stellate hairs with a specially differentiated basal portion and unicellular rays (in *Pomaderris*, &c.) ; and tufted hairs, the rays of which are mostly uniseriate and are inserted directly in the epidermis (in a group of closely allied species of *Rhamnus*). Extra-floral nectaries (?) are found on the lower side of the leaf in *Rhamnus glandulosa*, Ait.

STRUCTURE OF THE LEAF. The **stomata** are for the most part confined to the lower side of the leaf, but are found on both surfaces in certain species of *Colletia*, *Condalia*, *Cormonema*, *Crumenaria*, *Discaria*, *Gouania*, *Marlothia*, *Reissekia*, *Rhamnus*, *Scutia*, *Trevoa* and *Zizyphus*. Gemoll records stomata of the Cruciferous type in *Cryptandra obovata*, Sieb. and stomata of the Rubiaceous type in *Colletia spinosa*. Herzog mentions the occurrence of strikingly small and crowded stomata in species of *Reynosia* and *Sarcomphalus*, whilst he describes very large stomata in species of *Condalia*, *Discaria*, *Emmenospermum* and *Rhamnus*. Taking recent investigations into consideration, gelatinization of the **epidermis** of the leaf has been observed in species of the following genera : *Alphitonia*, *Berchemia*, *Ceanothus*, *Colubrina*, *Condalia* Sect. *Condaliopsis*, *Cormonema*, *Crumenaria*, *Cryptandra*, *Dallachya*, *Discaria*, *Emmenospermum*, *Gouania*, *Hovenia*, *Lamellisepalum*, *Lasiodiscus*, *Maesopsis*, *Paliurus*, *Pomaderris*, *Reissekia*, *Reynosia*, *Rhamnella*, *Rhamnidium*, *Rhamnus* Sect. *Frangula*, *Sageretia*, *Scutia* Sect. I, *Spyridium*, *Trevoa*, *Trymalium*, *Ventilago*, *Zizyphus* [1]. The process of gelatinization affects either all or only a certain number of the epidermal cells. The remaining characters of the epidermal cells (viz. height, cubical dimensions, nature of the lateral margins, thickening of the outer walls and pitting of the lateral walls) are subject to very considerable variation. The following features are specially noteworthy :—papillose protrusion of the epidermal cells (in most cases only on the lower side of the leaf) in species of *Berchemia*, *Discaria*, *Helinus*, *Karwinskia* and *Marlothia* ; development of typical papillae on the upper side of the leaf in *Cryptandra obovata*, Sieb., and on the lower side in *Karwinskia Humboldtiana*, Zucc. ; a two-layered epidermis in *Rhamnus Wightii*, W. et A. ; the occurrence of paired crystal-cells containing solitary crystals in the epidermis in *Ventilago leiocarpa*, Benth. **Hypoderm** (situated beneath the upper epidermis) is not of frequent occurrence ; it is present in *Microrhamnus ericoides*, A. Gray (here the upper layer of the hypoderm consists of mucilage-cells), *Reynosia revoluta*, Urb., *R. septentrionalis*, Urb., *Rhamnus Alaternus*, L. (in this species the hypoderm is confined to the margin of the leaf and is developed in the form of sclerosed mechanical tissue), *Sarcomphalus crenatus*, Urb., *S. domingensis*, Krug et Urb., *S. laurinus*, Griseb., *S. reticulatus*, Urb., *Ceanothus crassifolius*, Torr. and other species of the subgenus *Cerastes* (here tanniniferous). In most of the species the **mesophyll** is bifacial, but centric or subcentric leaves are also found. *Microrhamnus ericoides*, Gray has rolled leaves which are provided with a furrow on each side (to the right and left) of the median vein, and show centric structure ; regarding the occurrence of rolled leaves in *Phylica*, see Knoblauch, loc. cit. In the species of *Ceanothus* belonging to the subgenus

[1] In the previous (Syst. Anat., p. 218) enumeration of genera exhibiting this feature, the genus *Microrhamnus* should be cancelled ; the gelatinization of the epidermis of the leaf in *Hovenia* (*H. dulcis*, Thumb.) has only been correctly recorded by Blenk.

Cerastes the leaf also presents a characteristic appearance in transverse section. The lower surface of the leaf is provided with deep and narrow furrows, formed by the projecting network of the veins; the epidermis which lines these furrows includes the stomata and bears numerous hairs. The mesophyll is composed only of palisade tissue, which exhibits a larger number of layers at the bottom of the furrows and at the top of the ridges (formed by the projecting portions of the leaf-tissue) than along the lateral margins of the furrows. At the same time the vascular bundles of the veins are accompanied by large parenchymatous cells which contain tannin and merge into the hypoderm, situated on the upper side of the leaf (see above). In certain species (see Herzog, Sep. Copy, p. 113) the palisade-tissue consists of exceptionally long or short cells. In *Reynosia* and *Sarcomphalus* the spongy tissue is composed of elongated cells, which are interwoven with one another in such a way as almost to resemble a hyphal weft. Special features of the mesophyll are constituted by the above-mentioned enlarged palisade-cells, which are filled with mucilage (*Condalia lineata*, Gray, *C. mexicana*, Schlecht.) or tannin (*Condalia lineata*, *C. mexicana*, *Phyllogeiton discolor*, Herzog, *Scutia Commersonii*, Brongn., *Maesopsis berchemioides*, Engl., *M. Eminii*, Engl., *Rhamnella franguloides*, Weberhauer, *Pomaderris discolor*, Vent., *P. ferruginea*, Sieb., *P. lanigera*, Sims and *P. phylliraeoides* Sieb.) or both mucilage and tannin (*Discaria discolor*, Reiche, *D. serratifolia*, Benth. et Hook., *D. trinervis*, Reiche, *Talguenea costata*, Miers). *Cryptandra obovata*, Sieb. has a single layer of palisade-tissue, which is entirely composed of broad tanniniferous cells, while in *Zizyphus celtidifolius*, L. there is a middle layer consisting of mucilage-cells. In Herzog's summary the following structural characters of the **veins** are stated to be of value for systematic purposes. Vertical transcurrence of the lateral veins of the second order is found in *Alphitonia*, *Ceanothus*, *Colubrina*, *Cormonema*, *Crumenaria decumbens*, Mart. (not in *C. chortroides*, Mart.), *Helinus* (with the exception of *H. brevipes*, Radlk.), *Hovenia*, *Karwinskia*, *Pomaderris*, *Reynosia*, *Rhamnidium*, *Sageretia*, *Sarcomphalus*, species of *Zizyphus*; embedded veins occur in the Ventilagineae, Colletieae, Gouanieae (with few exceptions), and also in *Condalia*, *Emmenospermum*, *Krugiodendron*, *Lasiodiscus*, *Rhamnus*, *Scutia*, *Trymalium*, species of *Zizyphus*. There is a well-developed sheath of sclerenchyma around the lateral veins of the first order in the Ventilagineae, and also in species of *Berchemia*, *Emmenospermum*, species of *Gouania*, *Lamellisepalum*, *Lasiodiscus*, species of *Phylica*, *Reynosia*, *Sageretia*, *Sarcomphalus*, species of *Scutia* and of *Zizyphus*; the lateral veins of the second order are provided with a sheath of large parenchymatous cells, which are rich in tannin, in *Condalia*, *Krugiodendron*, *Microrhamnus*, species of *Rhamnus* (especially those of the subsection *Cervispina*) and species of *Zizyphus*.

The statements made in the earlier part of this work on the distribution of **oxalate of lime** may be extended in the following directions. Large solitary crystals occur in enlarged cells of the palisade-tissue in *Karwinskia*, *Reynosia Northropiana*, Urb., *Rhamnidium*, *Rhamnus* Sect. *Leptophyllius* Subsect. *Cervispina*, *Scutia* Sect. II, and *Zizyphus glabratus*, Heyne[1]. Large clustered crystals are found in enlarged cells of the mesophyll or palisade-tissue, as the case may be, in *Colubrina*, *Condalia*, *Cryptandra*, *Hovenia*, *Krugiodendron*, *Lasiodiscus*, *Pomaderris*, *Rhamnus* Sect. *Alaternus* and Sect. *Leptophyllius* Subsect. *Espina*, *Scutia* Sect. I, *Trevoa*, *Trymalium*, and species of *Zizyphus*. Large solitary and clustered crystals occur in a small group of closely allied species of *Rhamnus* (*R. costata*, Maxim., *R. nipalensis*, Laws., *R. Wightii*, W. et A.). The genus

[1] The earlier statement (p. 219) as to the occurrence of large solitary crystals in *Ceanothus* must be cancelled; it was based on Blenk's investigation of a plant described as '*Ceanothus macrophylla*, Wall.,' which does not belong to the Rhamneae. According to Gemoll, solitary crystals are wanting in *Ceanothus*.

Helinus (a member of the Gouanieae) as well as *Marlothia* have clustered crystals only and no styloids.

Among the internal **secretory receptacles**, the tannin- and mucilage-cells have already been dealt with in detail in describing the mesophyll. Secretory cavities are not only present in *Karwinskia* (three species), but also in *Rhamnidium* (three species) and *Reynosia reticulata*, Urb. They have an epithelium composed of several layers of flat cells, the innermost of which are drawn out into long finger-shaped protrusions terminating freely in the secretory space ; the contents are brown and do not dissolve easily. The secretory cavities are visible even to the naked eye as brown glandular dots. In *Reynosia revoluta*, Urb. the cavities are replaced by secretory canals having a similar epithelium and resinous contents, which are soluble in alcohol ; these canals run beneath the vascular system in the larger veins. Gemoll and Herzog have investigated the detailed distribution of the mucilage-receptacles (described as canals) found in the veins of the leaf. They have been recorded in the following genera : *Alphitonia, Berchemia, Ceanothus* pro parte (mucilage-cells ?), *Colubrina, Cormonema, Condalia* pro parte, *Dallachya, Emmenospermum, Gouania, Hovenia, Karwinskia, Lasiodiscus, Maesopsis, Paliurus, Phyllogeiton, Rhamnella, Rhamnidium, Rhamnus* Subgen. *Frangula, Sageretia, Scutia* Sect. I, *Ventilago* pro parte, *Zizyphus* (in almost all cases). The mucilage-receptacles are for the most part restricted to the principal veins and to the lateral veins of the first order. Their diameter varies, and an epithelium may or may not be present. They are situated in the collenchymatous tissue of the veins, and are either isolated or several of them lie side by side ; in *Maesopsis* they were met with in the phloem as well. Grès's paper also contains new statements on the distribution of these mucilage-receptacles, especially in the species of *Rhamnus* [1]. The same authority figures large mucilage-receptacles, occasionally containing clustered crystals, in different parts of the axis of certain species of *Rhamnus* (here situated in the inner portion of the primary cortex, in the pericycle, the pith and the secondary bast).

The following additional facts have become known regarding the **hairy covering** [2]. The glandular hairs mentioned by Gemoll as occurring on and near the margin of the leaf in *Ceanothus papillosus*, Torr. et Gray, correspond to the glandular leaf-teeth found in other members of the Order. They are glandular shaggy hairs with a multiseriate stalk containing the termination of a vascular bundle, and a spherical head provided with a secretory palisade epidermis. Special forms of clothing hairs are represented by the short papillose trichomes occurring in many species of *Cryptandra*, and the short peg-like hairs of *Zizyphus funiculosa*, Ham.; the latter recall the characteristic trichomes found in the Sapindaceous genera *Pancovia* and *Xerospermum*, and have a swollen basal portion, which appears striated owing to the presence of slit-shaped pits. Unicellular two-armed trichomes, which are seated on epidermal cells, occur in *Sageretia* and have already been noticed above. Mention has likewise been made of the stellate hairs found in the Pomaderreae ; these hairs have a stalk of varying length, and exhibit a variable number of ray-cells. Tufted hairs with 2–8 rays are found in the following species of *Rhamnus* : *R. californica*, Eschsch., *R. Palmeri*, Wats., *R. sectipetala*, Mart. and *R. sphaerosperma*, Sw. ; in *R. californica* the rays are unicellular, while in the other species they are

[1] Grès's statements do not quite tally with those of Herzog. Thus, according to Grès, mucilage-receptacles occur in the leaf of *Rhamnus cathartica*, L., *R. infectoria*, L. and *R. tinctoria*, W., as well as in the axis of *R. libanotica*, Boiss. and *R. Sibthorpiana*, i.e. they are present in some of the species of the subgenus *Eurhamnus*, whereas they are stated to be absent in *R. latifolia*, L'Hérit. (Subgen. *Frangula*).

[2] Swanlund's statement that 'hairs terminating in a spherical end-cell' are present in *Phylica nitida*, Lam. requires verification.

uniseriate. The small pits, observed by Clauditz in the axils of the lateral veins on the lower side of the leaves of *Rhamnus glandulosa*, Ait., are probably extra-floral nectaries; they are provided with a palisade epidermis and contain trichomes.

For the structure of the stipular spines of *Paliurus* see Lothelier; regarding the anatomy of the spiny branches of *Colletia* and *Rhamnus*, see Lothelier and Mittmann. The localization of Emodin and Frangulin in the cortex of *Rhamnus* is dealt with by Grès.

To the section dealing with the structure of the **cortex** we may add that the pericycle contains only isolated groups of bast-fibres in the species of *Alphitonia, Berchemia, Ceanothus, Colletia, Colubrina, Condalia, Emmenospermum, Hovenia, Paliurus, Rhamnus, Scutia, Ventilago*, examined by Petit, as well as in *Zizyphus sativa*.

Literature: Borscow, Frangulin, Bot. Zeit., 1874, p. 33.—Hohnel, Gerberinden, Berlin, 1880, p. 117.—Mittmann, Pflanzenstacheln. Verh. bot. Ver. Brandenburg, 1889, pp. 48–50.—[Pirotta, in Malpighia, iii, 1889, p. 61 et seq.; abstr. in Just, 1889, i, p. 606.]—Barber, Corky excresc., Ann. of Bot., vi, 1892, p. 165.—Lothelier, Épines. Thèse, Paris, 1893, pp. 14 and 31.—Cabannes, *Rhamnus*, Thèse. Montpellier, 1896, 72 pp.—Knoblanch, Ökolog. Anat., Habilitat.-Schr., Tübingen, 1896, p. 11 et seq.—[Planchon, Cascara Sagrada, Bull. d. Ph. d. S. E., i, 1896, n. 4; abstr. in Just, 1897, ii, p. 33.]—[Sayre, Frangula and Cascara bark, Americ. Journ. of Pharm., 1897, n. 3; abstr. in Just, 1897, ii, p. 32.]—Grès, Contribut. à l'étude anat. et microchim. des Rhamnées, Thèse, Paris, 1901, 104 pp., 2 pl.—Petersen, Vedanatomi, 1901, p. 50.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 39 and 90, 91.—Swanlund, Vegetat. Neuamsterdams u. St. Pauls, Diss., Basel, 1901, pp. 19–25 (*Phylica nitida*).—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 31–3 (*Rhamnus glandulosa*).—Gemoll, Anat.-syst. Unters. d. Bl. d. Rhamn. aus den Triben Rhamneen, Colletieen u. Gouanieen, Diss., München, in Beih. z. bot. Centralbl., xii, 1902, pp. 351–424.—[Finlayson, Stem-structure of some leafless plants, Transact. and Proceed. New Zealand Institute, 1903, p. 360 et seq. (*Discaria Toumatou*).]—Herzog, Anat.-syst. Unters. d. Bl. der Rhamneen aus den Triben Ventilagineen, Zizypheen u. Rhamneen, Diss., München, in Beih. z. bot. Centralbl., xv, 1903, pp. 95–207.—Sussenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 25.—Theorin, Växttrichom., Arkiv for Bot., iii, n. 5, 1904, p. 4.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 58, 59 (*Colubrina*).—[Mitlacher, Verf. v. Cortex Frangulae, Zeitschr. österreich. Apoth.-Ver., 1906, pp. 4–7; abstr. in Bot. Centralbl., ci, p. 462.]—Piccioli, Legnami, Bull. Siena, 1906, pp. 151, 157–9, and 161.—[For additional literature, see p. 1172.]

AMPELIDACEAE (pp. 221–226).

1. Review of the Anatomical Features. According to Gard, the first cork may in some cases develop in the bast and not in the pericycle. In the pith of *Tetrastigma* Kalberlah met with secretory canals with mucilaginous contents side by side with groups of mucilage-cells.

2. Structure of the Leaf. According to Gard's recent investigations, the leaves in the species of *Vitis* are mostly bifacial in structure, the palisade-tissue consisting of one or two layers; in rare cases the leaves exhibit a tendency towards centric structure. In *V. Labrusca*, L. the lower epidermis is subpapillose. The **petiole** in the species of *Vitis* contains isolated vascular bundles which are arranged to form a ring; in addition to the main system there are two cortical bundles on either side of the petiolar groove, and in rare cases further smaller bundles occur in the same position.

The following statements may be added regarding the features presented by the **crystals**. According to Gard, the shape of the individual raphides in *Cissus, Ampelopsis* and *Vitis* is characteristic of these genera, one end of each needle being pointed, while the other is bidentate, as in the gypsum-crystals found at Montmartre. According to the same authority, the raphides in the leaves (especially in the veins) of the species of *Euvitis*, Planch. are accompanied by clustered crystals, while in *V. rotundifolia*, Michx. and *V. Munsoniana*, Sims. (*V. Muscadinia*, Planch.) they occur side by side with prisms of oxalate of lime.

3. STRUCTURE OF THE AXIS. According to Gard, the wood-fibres, and the fibrous cells in the bast and pericycle of the '*Vites verae,*' are invariably septate by means of thin division-walls.

The cork develops subepidermally also in *Leea* (Hallier). Regarding the formation of the cork in the bast and the detailed differentiation of the cork-cells (with U-shaped or unilateral thickening) in *Vitis*, see Gard, ll. cc.

According to Gard, the arrangement of the hard bast in the species of *Vitis* belonging to the sections *Euvitis* and *Muscadinia* is different in the two cases and characteristic of each section. In *Euvitis* the phloem is stratified into hard and soft bast. In *Muscadinia*, on the other hand, the bast-fibres form more or less regular radial rows alongside of the medullary rays, and exhibit a scattered arrangement in the inner portion of each bast-group.

Literature: [Millardet, Hist. des princ. var. et espèces de vignes d'origine améric. etc., 1877–85: referred to by Gard, loc. cit.]—Kassner, Mark, Diss., Breslau, 1884, p. 21.—Keller, Luftwurzeln einiger Dikotyl., Diss., Heidelberg, 1889, pp. 23–6.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Hallier, in Natuurkundig Tijdschr. voor Ned.-Indie, lvi, 1896, pp. 308, 309.—Gauchery, Notes anat. sur qu. vignes hybrides, Assoc. franç. pour l'avancement d. sc., Congrès Nantes, 1898, ii, pp. 417–23.—Kalberlah, Bau von *Tetrastigma scariosum*, Zeitschr. f. Naturw., lxxi, 1898, pp. 161–218.—Gard, in Actes Soc. Linn. de Bordeaux, lv, 1900, pp. cxvii, ccii and ccvii; and lvi, 1901, pp. x, lxvii, lxx, cxxvii, and cxxx.—[Lopriore, Anat. di alcune Ampelid., Boll. Accad. Gioen. Sc. nat. Catania, 1901, 16 pp.; abstr. in Just, 1902, ii, p. 280.]—Molisch, Pflanzen als Trinkquellen, Deutsche Arbeit, i, 1901, p. 78 et seq.—[Ravaz et Bonnet, Bois de la vigne, Ann. de l'École nat. agr. de Montpellier, nouv. sér., i, 1901; abstr. in Bot. Centralbl., 1902, p. 451.]—Poulsen, Luftrødderne hos *Cissus sicyoides*, Vidensk. Meddelels. Kjøbenhavn, 1902, pp. 238, 239.—Gard, Ét. anat. sur les vignes, etc., Thèse, Bordeaux, 1903, 134 pp.; also in Actes Soc. Linn. de Bordeaux, lviii, 1903.—Tondera, Innerer Bau d. Sprosses von *Vitis vinifera*, Bull. internat. Acad. sc. Cracovie, 1904, pp. 91–6, 2 pl.; see also Abh. math.-naturw. Kl. Akad. Krakau, ser. 3, Bd. iv, B, 1904, pp. 43–54 (Polish).—Frommel, Plant. text. chil., 1905, p. 41.—Netolitzky, Dikotylenbl. (Rhaphiden), 1905, pp. 35–8.—Fries, Zwei südamerikan. Lianen, Botaniska Studier tillägn. Kjellman, 1906, p. 89 et seq.—Piccioli, Legnami, Bull. Siena, 1906, p. 133.—[For additional literature, see p. 1169.]

SAPINDACEAE (pp. 226–236).

APPENDIX: *On the Didiereae.*

We may append to the Sapindaceae a discussion of the genus *Didierea* (which was formerly regarded as a member of this Order by Baillon), and of the allied genus *Alluaudia*, both of which are distinguished by a Cactus-like habit. In the first place, however, it may be pointed out that these genera must be removed from the Sapindaceae; Radlkofer holds that *Didierea* is allied to the taxonomic group constituted by the Amarantaceae and Polygonaceae. Anatomically the two genera are characterized by the possession of mucilage-receptacles or mucilage-cells, the subepidermal development of the cork, and the occurrence of isolated bundles of pericyclic fibres.

Our knowledge of the anatomy of *Didierea* is as follows. The primary cortex contains spaces which are almost as big as a grain of millet and are filled with mucilage; near the surface there is a continuous layer of stone-cells, some of which are of very considerable dimensions, while on the outer side of this layer are situated cells containing large clustered crystals of oxalate of lime; finally, the greater part of the primary cortex consists of cells with brown tanniniferous contents, which in the living plant are possibly of the nature of latex. Cells with similar brown contents are also present in the pith. The bast-fibres form circular groups of varying size. The wood possesses broad medullary rays, wood-fibres bearing simple pits, and vessels with simple perforations. A transverse section through one of the linear leaves shows a homogeneous mesophyll containing tannin- and mucilage-cells, and 7–9 isolated vascular bundles, which are arranged in the form of an almost closed arc; the stomata are not present in large numbers and are only slightly depressed.

As regards the structure of the axis in *Alluaudia*, we may add that in *A. procera* the primary cortex contains mucilage- and tannin-cells, while in *A. ascendens* the

mucilage-cells are not isolated, but fuse to form mucilage-lacunae. The epidermis on both sides of the leaf of *Alluaudia* has a thick cuticle; beneath each epidermis there is a one-layered hypoderm, which at certain points, and especially in the neighbourhood of the stomata, shows an increase in the number of layers. On the upper side of the leaf the mesophyll consists of indistinct palisade-tissue. The stomata, which are found on the lower surface, are not numerous and are strongly depressed. A feature worthy of special note is the occurrence of clustered crystals of oxalate of lime in the epidermis of the leaf as well as in that of the stem.

Literature: R. Schenck, Qumacai cipó, Diss., Erlangen, 1894, 19 pp.—Radlkofer, in Natürl. Pflanzenfam., iii. Teil, Abt. 5, 1896, p. 462.—Schwabach, in Bot. Centralbl., 1898, iv, pp. 357–9.—[Radlkofer, Sapindaceae, in Martius, Flora brasil., xiii, 3, 1892–1900.]—Haberlandt, Sinnesorgane, 1901, p. 126 et seq.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 71.—Perrot et Guérin, *Didierea*, Journ. de bot., 1903, pp. 233–51.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet.-Akad. Handl., 39, n. 2, 1905, pp. 68, 69 and Tab. ii (*Nephelium*).—Haberlandt, Lichtsinnesorgane, 1905, p. 97.—Piccioli, Legnami, Bull. Siena, 1906, p. 176.—[Radlkofer, in Natürl. Pflanzenfam., Erg.-Heft ii, 1907, pp. 202–9; see also Nachtr. zum ii–iv Teil, 1897, p. 228.]

HIPPOCASTANACEAE (pp. 236–237).

The stomata on the leaves of *Aesculus californica*, Nutt. are provided with neighbouring cells which bear striate papillae, converging towards one another in a radiate manner.

Literature: Uhlworm, Entwicklungsgesch. d. Trichome, Bot. Zeit., 1873, p. 818.—Hohnel, Gerberinden, Berlin, 1880, p. 115 et seq.—Nanke, Blatt u. veget. Axen dikot. Holzpfl., Diss., Königsberg, 1886, p. 16 et seq.—Köhne, Papill. u. obers. Spaltöffn., Mitteil. dendrolog. Gesellsch., 1899, p. 58.—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 25, 26.—Bouygues, Cert. mérist. vasc. dans le pétiole, Act. Soc. Linn. Bordeaux, lvi, 1901, pp. lvii, lviii.—Pitard, Péricycle, These, Bordeaux, 1901, pp. 87, 88.—Bouygues, Pétiole, These, Paris, 1902, pp. 8 and 11.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 140.—Piccioli, Legnami, Bull. Siena, 1906, p. 142.

ACERACEAE (pp. 238–240).

1. Review of the Anatomical Features. According to Warsow, secretory sacs are present in the veins of the leaf in all the species of *Acer*, although their contents are milky only in a small number of cases. Latex-cells situated in the mesophyll, besides occurring in *A. campestre*, L., are found also in *A. pictum*, Thunb. and *A. neglectum*, Lang., which belong to the section *Platanoidea*[1]. Sausage-shaped or almost spherical idioblasts containing mucilage have been observed in the mesophyll in *A. laevigatum*, Wall. and *A. oblongum*, Wall. The clusters of calcium oxalate crystals occasionally resemble sphaerites; another form of excretion of oxalate of lime is that of small rod-shaped or acicular crystals, which are found in the mesophyll. In the genus *Acer* the unicellular clothing hairs are accompanied by uniseriate ones; two-armed hairs have been recorded also in *A. parviflorum*, Franch. et Sav.

2. Structure of the Leaf. The following statements are based on Warsow's recent investigations, which deal with eighty-five species and have led to certain improvements in Pax's system of classification.

The structure of the leaf is for the most part bifacial and rarely centric or subcentric. The palisade-tissue generally consists of a single layer of cells. The **stomata** are almost invariably confined to the lower side of the leaf; only in a few species (e.g. *A. japonicum*, Thunb.) do they occur in small numbers also on the upper side, where they are found in the neighbourhood of the veins. The lateral margins of the **epidermal cells** are straight or undulated, but in

[1] The nomenclature of the sections adopted here and in the following description is based on Pax's revision of the Aceraceae in Engler's 'Pflanzenreich.'

a few species (e.g. *A. Trautvetteri*, Medw. or *A. nikoense*, Maxim.) the cells of the lower epidermis have jagged margins. The cuticle occasionally exhibits striation, while in certain species it is covered by a layer of wax of varying thickness; the latter is the cause of the white colour presented by the lower surface of the leaf in *A. Drummondii*, Hook. et Arn., *A. niveum*, Bl. and *A. saccharinum*, L. Gelatinization of the epidermis of the leaf is remarkably common in the genus *Acer* (for details, see Warsow's paper), either affecting both upper and lower epidermis or only the upper epidermis. Papillose differentiation of the lower epidermis has been recorded in the following additional species: *A. caesium*, Wall., *A. Duretti*, Pax, *A. glabrum*, Torr., *A. griseum*, Pax, *A. Heldreichii*, Orph., *A. hybridum*, Spach, *A. insigne*, Boiss. et Buhse, *A. mandschuricum*, Maxim., *A. monspessulanum*, L., *A. nikoense*, Maxim., *A. niveum*, Bl., *A. ramosum*, Schwer., *A. sericeum*, Schwer., *A. sinense*, Pax, *A. sutchuense*, Franch. and *A. Trautvetteri*, Medw. Specially noteworthy features are: the occurrence of one or two small solitary crystals in cells of the lower epidermis in *A. erianthum*, Schwer. and *A. oblongum*, Wall., these cells being generally somewhat smaller than the remaining epidermal cells; and the presence of tanniniferous idioblasts in the lower epidermis in *A. villosum*, Wall. Hypoderm has not been recorded in any species of *Acer*. The larger **veins** almost invariably contain a ring of sclerenchyma; but in most of the species belonging to the section *Indivisa* there are only arcs of sclerenchyma or isolated sclerenchymatous elements. In all the species of *Acer* the smaller veins are vertically transcurrent by means of tissue with thin or thick walls.

Oxalate of lime is developed in relation to the vascular bundles of the veins; in a certain number of the species it is deposited mainly in the form of solitary crystals, while in the remainder it occurs principally in the form of clustered crystals. Large idioblasts which, in addition to smaller crystalline masses, contain a large solitary crystal, often placed with its long axis at right angles to the surface of the leaf, are found not only in *A. Negundo*, L., but also in the remaining species of the section *Negundo* (*A. californicum*, Dietr. and *A. mexicanum*, Pax), as well as in *A. cissifolium*, C. Koch; these elements cause transparent dots in the leaf. Similar idioblasts containing clustered crystals, which occasionally resemble sphaerites, are present in the species of the section *Indivisa* (with the exception of *A. carpinifolium*, S. et Z.), in *A. glabrum*, Torr. and in those of the section *Macrantha*. We have already pointed out above that according to Warsow the **secretory sacs** no doubt occur in all the species of *Acer*; they are situated in the bast in the vascular bundles of the veins and probably in the axis as well. In transverse sections of the leaf, which have been bleached with Eau de Javelle, they show up distinctly owing to their large lumina, but only in a small number (12 out of 85) of the species do they contain typical latex. These species are the following: *A. macrophyllum*, Pursh (which should perhaps be transferred from the Sect. *Spicata* to the Sect. *Platanoidea*); all the species of the section *Platanoidea* which have been investigated, viz. *A. laetum*, C. A. Mey., *A. Lobelii*, Ten., *A. Miyabei*, Maxim., *A. neglectum*, Lange, *A. pictum*, Thunb., *A. platanoides*, L., and *A. truncatum*, Bge.; *A. campestre*, L. (which should perhaps be removed from the Sect. *Campestria* and placed in the Sect. *Platanoidea*); lastly, *A. diabolicum*, Bl., *A. purpurascens*, Franch. et Sav. and *A. Thomsonii*, Miq., which belong to the section *Lithocarpa*. In the remaining species the contents are glassy and rather strongly refractive; they are readily soluble in alcohol and water, and are best seen by mounting dry transverse sections in olive-oil. The latex-cells and mucilage-idioblasts, occurring freely in the mesophyll in certain species, have already been referred to above.

The most widely distributed type in the **hairy covering** are unicellular clothing hairs. In some cases they are developed in the form of papillae, but

this type of differentiation is only found in species which have a papillose epidermis in the leaf, and in which the hairs constitute a transition to the papillae. As a rule, however, the clothing hairs are elongated structures, which are either wavy or stiff; in the latter case they may be straight or bent after the manner of a sabre. Uniseriate clothing hairs (composed of eight cells or less) are found only in a small number of species (mainly in the section *Platanoidea*). The ends of the clothing hairs are for the most part pointed, rarely (*A. parviflorum*, Franch. et Sav.) rounded. Two types of glandular hairs may be distinguished. The first of these, which is the most widely distributed, comprises approximately club-shaped glandular hairs with a uni- or biseriate stalk (mostly composed of 5 or 10 cells) and a multicellular head. A modification of this type of hair is found in the species of the section *Platanoidea*, in which the cells of the stalk are flat and the head spherical. The second type of glandular hair is constituted by uniseriate external glands, which in certain species pass over into (multiseriate) shaggy hairs; a peculiar form of trichome, which may be noticed in this connexion, is that of glandular shaggy hairs, which exhibit division into two uniseriate glands at a point situated at a varying distance from the base of the trichome. The second type of external gland occurs in the species of the section *Indivisa* (with the exception of *A. carpinifolium*, S. et Z. and *A. distylum*, S. et Z.), in *A. rubrum*, L. and in the species of the section *Macrantha* (excepting *A. parviflorum*, Franch. et Sav.).

For the vascular system of the **petiole**, see also Bouygues and Col, ll. cc.

Literature: Gregory, Cork wings, Bot. Gaz., 1888, pp. 281, 282.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Köhne, Papill. u. oberseit. Spaltöffn., Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 58.—Hämmerle, *Acer Pseudoplatanus*, Bibl. bot., Heft 50, 1900, 101 pp.—Petersen, Vedanatomi, 1901, p. 47.—Bouygues, Petiole, Thèse, Paris, 1902, p. 11.—Pax, in Pflanzenreich, Heft 8, 1902, p. 2.—Tuzson, Spiralige Strukt. d. Zellw. in den Markstr., Ber. deutsch. bot. Gesellsch., 1903, p. 276.—Warsow, Syst.-anat. Untersuch. d. Bl. bei d. Gatt. *Acer*, etc., Diss., Erlangen, 1903, 109 pp.; sep. copy from Beih. z. Bot. Centralbl., xv, p. 493 et seq.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 136–9.—Süssenguth, Behaarungsverh. der Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 24.—Haberlandt, Lichtsinnesorg., 1905, pp. 105, 106 and Tab. iii.—Theorin, Växttrichom., Arkiv för Bot., iv, n. 18, 1905, pp. 2, 3.—Piccioli, Legnami, Bull. Siena, 1906, p. 138.

STAPHYLEACEAE (pp. 242, 243).

Literature: Piccioli, Legnami, Bull. Siena, 1906, p. 130.

SABIACEAE (pp. 243, 244).

The exact nature of the 'poches sécrétrices,' mentioned by Pierre (in Flore forest. de la Cochinchine, xxiii, 1897) as occurring in *Meliosma Cambodiana*, must be made the subject of renewed investigation, in view of the fact that in other species of *Meliosma* Radlkofer has recorded the presence of cells having siliceous contents (not resin-cells, see p. 243).

Literature: Pierre, loc. cit., 1897.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 76 and 94.—[Dihm, Blatt d. Gatt. *Meliosma* in anat. Hinsicht, Beih. z. bot. Centralbl., xxi, Abt. 1, 1907, 31 pp. and Tab. v, vi.]

ANACARDIACEAE (pp. 244–248).

1. Review of the Anatomical Features. To the statements on the hairy covering we may add that simple uniseriate clothing hairs, as well as branched (glandular ?) multicellular trichomes also occur in this Order.

2. Structure of the Leaf. The **mesophyll** is bifacial in most of the species of *Rhus* of the section Gerontogeae, Engl., which have been investigated

by Diels; in *R. incisa*, L. f. it consists of palisade-tissue only. In the species of *Rhus*, belonging to the section just named, the stomata are either confined to the lower side or occur on both sides of the leaf. In *R. Burkeana*, Sond. they are deeply sunk and provided with a vestibule, the inner margin of which is formed by the neighbouring cells of the stoma, which project considerably beyond the level of the epidermis. Papillae are found on the lower side of the leaf also in *R. Cotinus*, L. (according to Knothe) and *R. Osbecki*, DC. (according to Köhne). Regarding the **hairy covering** we may add the following facts. The uniseriate trichomes occurring in certain species of *Rhus* are bi- to multicellular and have pointed or blunt ends. *R. horrida*, Eckl. et Zeyh. has stellate trichomes with thin walls, the ray cells of which show a radial arrangement and lie in a plane parallel to the surface of the leaf; similar trichomes, which, however, exhibit irregular orientation of the ray-cells, are found in *R. somalensis*, Engl., while *R. incana*, Engl. has irregularly branched trichomes composed of a large number of cells; all these different forms of hairs may possibly have a glandular function. Among the types of glandular hairs observed by Diels we may mention the external glands found in *R. discolor*, E. Mey; they have a unicellular stalk and a unicellular glandular head of variable shape. Small peltate glands with irregularly arranged glandular cells have been recorded also in *Campnosperma* (Fabricius).

3. STRUCTURE OF THE AXIS. Silica-bodies are found in the wood-parenchyma in *Melanorrhoea obtusifolia*, Engl. (Bargagli-Petrucci).

The contents of the **secretory canals** are sometimes (species of *Rhus*) of the nature of latex; see also Molisch, loc. cit.

Literature: [Vogl, Gum of Quebracho colorado, Pharm. Journ. and Transact., 1880; abstr. in Bot. Centralbl., 1880, p. 1042.]—Jadin, Org. sécrét., Thèse, Montpellier, 1888, p. 45 et seq.—J. E. Weiss, Korkbild., Denkschr. bot. Gesellsch. Regensburg, vi, 1890, p. 64.—Jadin, Qu. Térébinth., Journ. de bot., 1893, p. 382 et seq.—Knoblanch, Oekolog. Anat. etc., Habilitat.-Schr., Tübingen, 1896, p. 11 et seq.—Werner, Neuere Drogen, Diss., Erlangen, 1896, pp. 1–10 (*Cortex Comocladiae*).—Diels, Epharmose d. Vegetationsorg. bei *Rhus*, L. § *Gerontogeae*, Engl., in Engler, Bot. Jahrb., xxiv, 1898, pp. 568–647 and Tab. xiv.—Pierre, Flore forest. de la Cochinchine, xxiv, 1898 (*Dracontomelum*), and xvii, 1892 (*Mangifera*).—Köhne, Papill. u. oberseit. Spaltöffn., Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 58.—Möbius, Der japan. Lackbaum, *Rhus vernicifera*, Abh. Senckenberg. Gesellsch., xx, 1899, pp. 210–27.—Inui, Gummiharzgang d. Lackbaumes, etc., Bot. Centralbl., 1900, iii, p. 352.—Briquet, Anat. comp. de la feuille chez les *Pistacia Lentiscus*, etc., Bull. de l'Herbier Boissier, sér. 2, t. i, 1901, pp. 1301–5.—Molisch, Milchsaft u. Schleimsaft, 1901, p. 25, footnote 1.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 40 and 74.—Bargagli-Petrucci, Concrez. silicee, Malpighia, 1902, p. 23 et seq.; and Legnami, loc. cit., p. 319 et seq. (*Campnosperma*, *Melanochyla*, *Melanorrhoea*, *Pentaspadon*).—Bouygues, Pétiole, Thèse, Paris, 1902, p. 12.—Fabricius, Laubblatt-Anat., Beih. z. bot. Centralbl., xii, 1902, pp. 311, 312.—Knothe, Unbenetzbare Bl., Diss., Heidelberg, 1902, p. 10.—Simon, in Ber. deutsch. bot. Gesellsch., 1902, p. 241.—[Armari, Piante della reg. medit., Ann. di Bot., i, 1903, p. 17 et seq. (*Pistacia*).]—Quanjer, Anat. bouw, etc., Natuurk. Verhandel. Haarlem, iii, 5, 1903 (*Gluta Benghas* and *Buchanania* sp.).—Ursprung, in Bot. Zeit., 1904, p. 198.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 76, 77 (*Mangifera*), and pp. 124, 125 (*Anacardium*).—Sarton, Anat. d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 63–79 (*Pistacia*).—Piccioli, Legnami, Bull. Siena, 1906, pp. 141, 150 and 160.—[For further literature, see p. 1169.]

CORIARIEAE (p. 249).

Oxalate of lime is found in the form of clustered crystals also in the rhizome of *Coriaria myrtifolia*.

Literature: Villeneuve, Le Redoul, Thèse, Montpellier, 1893, 62 pp., especially pp. 20–37.

MORINGEAE (pp. 249, 250).

Guignard's discovery of the occurrence of **myrosin-cells** in this Order is of great importance in interpreting the taxonomic relations between the Moringeae and the Capparideae.

Jadin has investigated the distribution of the myrosin in detail in *Moringa pterygosperma*. According to him the myrosin-cells of the root are situated in the bast and primary cortex, myrosin being distributed throughout the peripheral layers of the cortex. In the branch, myrosin-cells are likewise present in the bast and the primary cortex (here especially in the subepidermal layer of cells). Similar cells occur also in the mesophyll.

Literature: Jadin, Localisat. de la myrosine et de la gomme chez les *Moringa*, Comptes rendus Paris, 1900, 1. Sem., pp. 733–5.

CONNARACEAE (pp. 250–253).

Pierre records small secretory cells and a hypoderm in the leaf in *Cnestis ramiflora*, Griff., secretory cells and an almost sclerosed palisade-tissue composed of two layers in *Aglaia Cambodiana*.

A composite and continuous ring of sclerenchyma is developed in the pericycle also in *Connarus paniculatus* (Pitard).

Literature. Bartels, Cangoura, Diss., Erlangen, 1894, pp. 28, 29.—Costeros, *Connarus*, Ann. Jardin Buitenzorg, Suppl. ii, 1898, pp. 109–12 and pl. iv.—Pierre, Flore forest. de la Cochinchine, xxiv, 1898.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 83.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 111, 112 and Tab. xiv, xv (*Connarus*.—[Sperlich, Opt. Verh. in d. oberseit. Blattepidermis, Sitz.-Ber. Wiener Akad., cxvi, Abt. 1, 1907, p. 718.]

LEGUMINOSAE (p. 253).

I. Papilionaceae (pp. 253–281).

1. Review of the Anatomical Features. The following additional facts have been recorded:—

Internal secretory organs (p. 254):—Mucilage-cells are found in *Caragana*, and mucilage-lacunae in *Alhagi* and *Halimodendron*. Secretory cavities in the form of ordinary intercellular spaces filled with secretion occur in *Anthyllis Genistae*, Duf., while closed schizogenous secretory cavities are present in the leaf in the monotypic genus *Cordyla*. Lastly, schizogenous secretory canals are found in the primary cortex of the branch in *Cordyla*.

Oxalate of lime (p. 254):—Small crystalline grains or needles are not uncommon in the Podalyrieae and Genisteae, and occur also in members of the Trifolieae, Loteae and Vicieae.

Hairy covering (pp. 254, 255):—Of special forms of clothing hairs three-celled trichomes having a two-armed terminal cell are present also in certain Podalyrieae and Genisteae. With reference to the distribution of the external glands we may note that, taking the results of the earlier investigations into consideration as well, they are of frequent occurrence only in the Tribes Trifolieae, Galegeae, Hedysareae, Vicieae, Phaseoleae and Dalbergieae, while they are absent in the Podalyrieae, Sophoreae and Swartzieae, and are only rarely met with in the Genisteae and Loteae.

Special anatomical features (p. 255):—Pseudo-pitting or internal striation of the epidermal cells of the leaf (certain Podalyrieae and Genisteae); epidermal cells of the leaf having a prosenchymatous shape (species of *Lathyrus*) or elon-

gated transversely to the midrib (species of *Eutaxia* and *Trifolium*); a peculiar depression of the stomatal apparatus (species of *Jacksonia*); restriction of the stomata to the upper side of the leaf (in certain Podalyrieae which have rolled leaves with a furrow on the upper side); transverse arrangement of the stomata on the leaves (species of *Anarthrophyllum*, *Eutaxia*, and *Latrobea*) or on the assimilating axes (*Daviesia divaricata*, Benth.); spicular fibres in the mesophyll (species of *Pultenaea*, *Dillwynia*, *Bossiaea*); special structural features presented by the veins of the leaf (' double vascular bundles ' in *Daviesia*, annular arrangement of the vascular bundles of the leaf, &c.); lastly, the occurrence of sphaerocrystalline masses or of bodies resembling indigo or indican in the mesophyll.

Anomalies in the structure of the stem (p. 255):—Successive rings of growth occur also in *Strongylodon*.

2. STRUCTURE OF THE LEAF. In recent times a detailed investigation of the structure of the leaf has also been undertaken in the Podalyrieae (by Prenger [1], Bürkle [2] and Hühner [3]), the Genisteae (by Schroeder [4], Cohn [5], Winkler [6], Levy [7], H. Schulze [8], W. Schulze [9] and Rauth [10]), the Trifolieae (by G. Fischer [11]), the Loteae (by W. Schmidt [12]) and the Vicieae (by Streicher [13]).

The **epidermis** of the leaf in these groups shows features similar to those found in the Tribes previously investigated, the characters being for the most part of value in specific diagnosis. In many Podalyrieae and also in certain Genisteae the cuticle exhibits verrucose thickenings; this feature is commonly combined with the penetration of peg-shaped or lamella-like processes of the cellulose-membrane into the outer cuticularized portion of the external wall; this leads to a peculiar structure as seen in surface-view (' pseudo-pitting ' or ' internal striation '). Lateral walls exhibiting angular folds have recently been observed also in *Anagyris foetida*, Ten., species of *Ononis*, *Trigonella*, *Melilotus* and *Trifolium*, and species of *Securigera*, *Dorycnium*, *Lotus* (see Syst. Anat., p. 256, footnote 1), *Anthyllis*, *Hymenocarpus* and *Hosackia*; epidermal cells of prosenchymatous shape have been recorded in species of *Lathyrus*; epidermal cells elongated transversely to the midrib in species of *Eutaxia* and *Trifolium*; special small (empty ?) cells in the epidermis in certain species of *Lupinus*. Formation of papillae is a common feature; the papillae vary in shape, are sometimes solid or reduced to cuticular humps, and may be present either on both surfaces of the leaf or only on one. An important point with reference to the gelatinization of the epidermis lies in the fact that epidermal cells with mucilaginous inner membranes have not been observed in any member of the Loteae, Trifolieae or Vicieae.

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[1] Species of the following genera were examined: *Anagyris*, *Piptanthus*, *Thermopsis* and *Baptisia* (northern hemisphere); *Cyclopia* and *Podalyria* (Cape of Good Hope); *Brachysema*, *Oxylobium*, *Chorizema* and *Mirbelia* (Australia).

[2] Species of *Isotropis*, *Gompholobium*, *Burtonia*, *Jacksonia*, *Sphaerolobium*, *Viminaria*, *Daviesia*, *Aotus*, *Phyllota*.

[3] Species of *Gastrolobium*, *Pultenaea*, *Latrobea*, *Eutaxia*, *Dillwynia*.

[4] Species of *Liparia*, *Priestleya*, *Amphithalea*, *Lathriogyne*, *Coelidium*, *Platylobium*, *Bossiaea*, *Templetonia*, *Hovea*, *Goodia*.

[5] Species of *Borbonia*, *Rafnia*, *Euchlora*, *Lotononis*, *Rothia*, *Lebeckia*, *Viborgia*.

[6] Species of *Crotalaria* and *Prioritropis*.

[7] Species of *Aspalathus*, *Buchenroedera*, *Melolobium*, *Dichilus*, *Heylandia*.

[8] Species of *Lupinus* and *Argyrolobium*.

[9] Species of *Genista* with *Anarthrophyllum*, *Adenocarpus*, *Calycotome*.

[10] Species of *Laburnum*, *Petteria*, *Spartium*, *Erinacea*, *Ulex*, *Cytisus*, *Hypocalyptus* and *Loddigesia*.

[11] Species of *Ononis*, *Trigonella*, *Medicago*, *Melilotus*, *Trifolium*.

[12] Species of *Anthyllis*, *Helminthocarpum*, *Hymenocarpus*, *Securigera*, *Cytisopsis*, *Dorycnium*, *Lotus*, *Hosackia*.

[13] Species of *Cicer*, *Vicia*, *Lens*, *Lathyrus*, *Pisum*, *Abrus*.

The pseudo-pitting or internal striation above referred to has been observed in the following cases: (1) among the Podalyrieae, in species of *Cyclopia*, *Podalyria*, *Oxylobium*, *Gompholobium*, *Daviesia*, *Aotus*, *Burtonia* (here penetrating into the papillae in the form of radiating tufts), *Pultenaea*; (2) among the Genisteae, in species of *Aspalathus*, and in *Lupinus coriaceus*, Benth.

Papillose epidermal cells have recently been observed as follows: (1) among the Podalyrieae, in species of *Cyclopia*, *Brachysema*, *Oxylobium*, *Chorizema*, *Mirbelia*, *Gompholobium*, *Burtonia*, *Sphaerolobium*, *Daviesia*, *Aotus*, *Phyllota*, *Gastrolobium*, *Pultenaea*, *Latrobea*, *Eutaxia*, *Dillwynia*; (2) among the Genisteae, in species of *Liparia*, *Priestleya*, *Coelidium*, *Bossiaea*, *Templetonia*, *Hovea*, *Goodia*, *Crotalaria*, *Prioritropis* (*P. cytisoides*, W. et A.), *Lupinus* (only isolated epidermal cells), *Argyrolobium* (only isolated epidermal cells), *Genista* (also in *G. pilosa*, L. according to Köhne, cf. W. Schulze), *Adenocarpus*, *Calycotome*, *Laburnum*, *Spartium*, *Cytisus*, *Hypocalyptus*, *Loddigesia*; (3) among the Trifolieae, in species of *Trifolium*; (4) among the Loteae, in species of *Anthyllis*, *Dorycnium*, *Lotus*, *Hosackia*; (5) among the Vicieae, in *Abrus tenuiflorus*, Spruce; (6) among the Galegeae, also in *Indigofera Gerardiana*, Wall. (according to Köhne [1]). Specially noteworthy forms are the papillae of *Burtonia scabra*, R. Br. and *B. villosa*, Meissn., which are provided with a coronulate apex and are connected by reticulate cuticular ridges, and the papillae of *Dillwynia*, especially *D. hispida*, Lindl., which form longitudinal rows projecting in the form of ridges.

Epidermal cells with mucilaginous inner membranes have been recorded in the following cases: (1) among the Podalyrieae, in species of *Cyclopia*, *Brachysema*, *Oxylobium*, *Chorizema*, *Mirbelia*, *Burtonia*, *Sphaerolobium*, *Viminaria*, *Aotus*, *Phyllota*, *Gastrolobium*, *Pultenaea*, *Latrobea*, *Eutaxia*, *Dillwynia*; (2) among the Genisteae, in species of *Platylobium*, *Bossiaea*, *Templetonia*, *Hovea*, *Goodia*, *Borbonia*, *Rafnia*, *Euchlora*, *Lotononis*, *Rothia*, *Lebeckia*, *Viborgia*, *Aspalathus*, *Melolobium*, *Dichilus*, *Heylandia*, *Crotalaria*, *Prioritropis*, *Argyrolobium*, *Genista*, *Adenocarpus*, *Calycotome*, *Laburnum*, *Petteria*, *Spartium*, *Erinacea*, *Ulex*, *Cytisus*.

Hypoderm has recently been recorded among the Podalyrieae in species of the genera *Daviesia* (on both sides), *Pultenaea*, *Eutaxia* and *Dillwynia* (here on the lower side, and filled with brown contents), as well as in *Crotalaria lunulata*, Heyne (on the upper side) and *Cicer subaphyllum*, Boiss. (here in the leaf-spines). Thin vertical walls are found in the epidermal cells in species of *Petteria* (in the neighbouring cells of the stomata) and *Cytisus*.

There is again no uniformity in the type of stoma found in the Tribes Podalyrieae, Genisteae, Trifolieae, Loteae and Vicieae. In the Podalyrieae the pairs of guard-cells are very often surrounded by a varying number of ordinary epidermal cells, but the following additional types of **stomata** have been noticed in this Tribe: stomata with four neighbouring cells, two of which are parallel to and situated to the right and left of the pore (in species of *Brachysema*, *Oxylobium*, *Dillwynia*, and in *Aotus cordifolia*, Benth.); stomata with three neighbouring or subsidiary cells (in species of *Jacksonia*, *Sphaerolobium*, *Gastrolobium*, *Pultenaea* and *Latrobea*); and stomata of the Rubiaceous type (in species of *Jacksonia*, *Eutaxia* and *Dillwynia*). In the Genisteae the following types are found: stomata approximating to the Cruciferous type (in species of *Rafnia*, *Borbonia*, *Lotononis*, *Lebeckia*, *Viborgia*, *Crotalaria*, *Prioritropis*); stomata showing an approximation to the Rubiaceous type (in *Hovea*, *Hypocalyptus* and *Borbonia crenata*, L.; in the last only some of the stomata belong to this type); and lastly, stomata surrounded by a rosette of epidermal cells of the nature of subsidiary cells (in *Templetonia*, *Lebeckia psiloloba*, Walp. (on the axis), and species of *Anarthrophyllum* and *Genista*). For most of the Trifolieae Fischer records 3-4 (rarely more) neighbouring cells arranged according to the Ranunculaceous type; *Ononis* alone follows

[1] In Köhne's paper (loc. cit.) a number of species of *Colutea* and *Robinia* are also mentioned as having a papillose epidermis in the leaf; Weyland, who investigated the Galegeae, did not examine these species.

the Rubiaceous type. According to Schmidt, the neighbouring cells (numbering usually 3–4, rarely 2 or 6–7) of the stomata in the Loteae are not specialized. Nor, according to Streicher, are those of the Vicieae; but in species of *Cicer*, *Vicia*, *Lens* and *Lathyrus*, a small number of stomata have been observed with a parallel subsidiary cell situated to the right and left of the pore; in *Abrus* there are four subsidiary cells, of which one is occasionally placed on either side of and parallel to the pore. The stomata situated on the assimilating branches of certain species of *Jacksonia* are sunk and require special mention. The pores of the stomata are here placed parallel to the vertical direction, and are accompanied either by two (in this case parallel to the pore) or three subsidiary cells, which have remarkably thin walls; the guard-cells, together with their subsidiary cells, are sunk in the surface of the branch in a deep pit, which generally has a long, narrow outline. On that part of the margin of the pit, moreover, which is situated nearest the base of the stem, a hair is inserted, the terminal cell of which has thin walls and wide lumina and covers in the pit. With reference to the distribution of the stomata on one or both surfaces of the leaf, the following facts may be mentioned: in the Trifolieae and Loteae which have been investigated, the stomata are invariably present on both sides; in the rolled leaves of certain genera of the Podalyrieae (viz. *Pultenaea*, *Eutaxia* and *Dillwynia*, in which the leaves are furrowed on the upper surface), as well as in *Coelidium* (Tribe Genisteae), the stomata are confined to the upper side[1]. The stomata are very commonly placed parallel to one another, their pores being at the same time directed parallel to the midrib of the leaf. A more striking feature is furnished by stomata which lie parallel to one another, but are arranged transversely to the midrib of the leaf or to the vertical axis of the branch, as the case may be; e.g. on the leaves in species of *Eutaxia* and in *Latrobea tenella*, Benth., and on the assimilating axes of *Daviesia divaricata*, Benth. (Tribe Podalyrieae), as well as on the leaves of *Anarthrophyllum Cumingii*, Phil. f. and *A. andicolum*, Phil. f.

The following features of the **mesophyll** may be noted: the central pith-like tissue, found in the terete or narrow leaves of species of *Daviesia* and *Lebeckia*; the parenchyma in the interior of the acicular leaves of species of *Aspalathus*, which envelops the vascular system and resembles a pith; the occurrence of weakly developed spicular fibres, which are connected with the sclerenchyma of the veins, in species of *Pultenaea*, *Dillwynia* and *Bossiaea*, and of sclerosed parenchymatous cells in species of *Buchenroedera*.

For details as to the structure of the **veins**, the reader is referred to the papers cited below. The smaller veins of the leaf are vertically transcurrent in certain Podalyrieae, Genisteae, Trifolieae (species of *Trifolium*) and Vicieae (*Abrus*). Sclerenchyma is occasionally not developed in the veins; this is specially often the case among the herbaceous species. According to Streicher, the sclerenchyma in the veins of *Vicia*, *Lathyrus*, *Lens* and *Pisum* is confined to the side on which the xylem is situated. In those species of *Daviesia* (Tribe Podalyrieae), in which the leaves are approximately horizontal and of some breadth, the median veins consist of two opposite systems of vascular bundles with their xylem-groups abutting on one another ('double vascular bundles'); the lateral veins either contain 'double vascular bundles' of the same type, or exhibit a row of simple bundles in transverse section, the xylem-groups of these bundles being directed alternately towards the upper and lower side of the leaf. An annular arrangement of the vascular

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[1] Köhne (loc. cit.) states that the stomata are confined to the upper side of the leaf also in *Genista hispanica* and *G. sericea*, as well as in *Lespedeza sericea* (Hedysareae); according to W. Schulze this is incorrect in the case of the first two species.

bundles is found also in the leaves of the species of *Lebeckia*, which contain a tissue resembling a pith in their interior. Sheaths composed of large parenchymatous cells occur in certain Podalyrieae, Genisteae and Loteae, and enlarged terminal tracheids or storage-tracheids are present in certain representatives of the same three Tribes.

In dealing with the **secretory organs** we will first consider the tannin-sacs. Their distribution in the Tribes which have been recently investigated is as follows: They are present in the leaf in certain Podalyrieae and Loteae; in the Tribe Genisteae they occur only in *Goodia*; in the Tribe Trifolieae distinctly differentiated sacs have been demonstrated only in *Parochetus*; and in the Tribe Vicieae they are altogether wanting.

To the synopsis on p. 260 we may add:—1 *a*. Podalyrieae: According to Prenger, Bürkle and Hühner, tannin-idioblasts are found in the leaves of certain species of *Cyclopia*, *Brachysema*, *Oxylobium*, *Chorizema*, *Mirbelia*, *Aotus*, *Phyllota*, *Pultenaea*, *Latrobea*, *Eutaxia* and *Dillwynia*. 1 *b*. Genisteae: Schroeder records the occurrence of sac-shaped tannin-cells in the palisade-tissue, and of a hypodermal layer of cells filled with brown contents in the spongy tissue in *Goodia*, a genus which is anomalous also in the possession of trifoliate leaves, and should probably be transferred to the Galegeae. 2. Trifolieae: Tannin-sacs have been observed by G. Fischer only in the parenchyma of the veins of *Parochetus communis*, Hamilt.; they have wide lumina and are arranged in rows. 3. Loteae: According to W. Schmidt, tannin-sacs occur in the leaves in *Anthyllis* pro parte, *Helminthocarpum*, *Cytisopsis*, *Dorycnium*, *Lotus* pro parte, and *Hosackia* (but not in *Hymenocarpus* and *Securigera*). 6 *a*. Vicieae: According to Streicher, there are no tannin-sacs in the leaf. 9. Swartzieae: According to Guignard, tannin-sacs are present also in *Cordyla* (primary cortex and parenchymatous pericycle).

Other types of secretory cells have recently been observed by Jönsson, viz. mucilage-sacs in the palisade tissue of '*Caragana frutescens*, DC.' and mucilage-cells in the secondary cortex of *Alhagi camelorum*, Fisch. With these we may class the mucilage-lacunae which the same author found in older parts of the axis of *Alhagi camelorum* and *Halimodendron argenteum*, DC.; these lacunae are situated in the secondary cortex in the former species, and in the pith and secondary cortex in the latter. We may also point out here that *Lebeckia* ? *retamoides*, in which G. Cohn found rounded secretory cells with resinous contents, belongs to the genus *Tephrosia* (see Solereder, loc. cit.).

Secretory cavities have also been demonstrated in *Anthyllis Genistae*, Duf.[1] They are confined to the leaf, and consist of ordinary intercellular spaces filled with a bright yellow resinous secretion, which is soluble in alcohol; they are connected with the remaining intercellular spaces and thus recall the secretory receptacles found in *Derris*, &c.[2] According to Guignard, closed schizogenous secretory cavities occur in the leaf of *Cordyla africana*, Lour. (Tribe Swartzieae); in the branch of the same plant they are replaced by schizogenous secretory canals (situated in the primary cortex, but not in the pith or wood).

New forms of crystals of **oxalate of lime** or typical clustered crystals

[1] In view of the isolated occurrence of secretory cavities in this species (the cavities are wanting in the closely related *A. cytisoides*, L. and *A. Hermanniae*, L.) it may be expressly pointed out that a leaflet of the original plant (Herb. DC.) has also been examined.

[2] Secretory cavities, provided with a loose papillose epithelium (similar to those found in certain species of *Lonchocarpus*) have recently been recorded by Geiger (see also Duval) also in *Swartzia decipiens*, Holmes, the leaves of which constitute a new form of adulteration of Jaborandi-leaves. In all probability, however, *S. decipiens*, Holmes no more belongs to the genus *Swartzia* than does the plant (Spruc., No. 1197, Brasil) previously investigated by Köpff and described as *S. alterna*, Benth.; the latter exhibits 'secretory masses enveloped by bracket-cells,' as in certain species of *Lonchocarpus* and *Derris*.

have not been recorded[1]. All the Australian genera of the Podalyrieae possess ordinary large rhombohedral crystals or hemitropic forms of such crystals, which are often rod-shaped; the crystals of this type are occasionally accompanied by small prismatic or acicular crystals. The latter are the only forms of crystals present in the genera endemic in the region of the Cape (*Cyclopia* and *Podalyria*) and in those inhabiting the northern hemisphere (*Anagyris*, *Piptanthus*, *Thermopsis* and *Baptisia*). Among the Genisteae ordinary large crystals or their hemitropic forms occur only in *Platylobium*, *Bossiaea*, *Templetonia*, *Hovea* and *Goodia*, while small, cubical, prismatic or acicular crystals are found in *Liparia*, *Priestleya*, *Amphithalea*, *Lathriogyne*, *Coelidium*, *Borbonia*, *Lebeckia*, *Viborgia*, *Aspalathus*, *Melolobium*, *Crotalaria*, *Prioritropis*, *Lupinus*, *Argyrolobium*, *Genista*, *Anarthrophyllum*, *Adenocarpus*, *Calycotome*, *Petteria*, *Spartium*, *Ulex*, *Cytisus*, and *Hypocalyptus*. Among the Trifolieae *Parochetus* is the only genus in which ordinary solitary crystals are absent; together with crystals of this type small crystals occur in the mesophyll or epidermis. In the Tribe Loteae, ordinary solitary crystals have likewise been demonstrated in all the genera with the exception of *Helminthocarpum*; in certain species of *Lotus* and *Dorycnium* these crystals attain a specially large size and have a distinct styloid-like shape; crystalline grains have also been observed in certain species of *Anthyllis*, *Securigera*, *Lotus* and *Hosackia*. Lastly, ordinary large solitary crystals have been recorded also in the genera of the Vicieae; in species of *Cicer*, *Vicia* and *Lathyrus* small crystalline bodies are found.

Cells filled with rod-shaped crystals (cf. p. 266) have recently been observed in the palisade-tissue in the following species: among the Podalyrieae, in species of *Isotropis*, *Daviesia*, *Pultenaea*, *Latrobea* and *Eutaxia*; among the Genisteae, apparently (see Schroeder) in species of *Platylobium*, *Bossiaea*, *Templetonia* and *Hovea*; among the Trifolieae, only in *Ononis speciosa*, Lag. and a few species of *Trifolium*; among the Loteae, in species of *Anthyllis*, *Cytisopsis*, and *Lotus* (*L. trichocarpus*, Lag.); among the Vicieae, in species of *Vicia* (*V. Gerardi*, Vill.), *Lathyrus* (*L. aureus*, Stev.), and *Abrus* (*A. Schimperi*, Hochst.); among the Dalbergieae, also in *Derris elliptica*, Benth. (according to Quanjer).

To the enumeration (on p. 266) of species having large solitary crystals in the epidermis of the leaf we may add *Abrus precatorius*, L. (Tribe Vicieae). In this species both the upper and lower epidermis contain small groups of 2–7 (mostly 4) cells, each of which encloses a rod-shaped crystal; the latter is embedded in the thickened inner wall of the epidermal cell with its longitudinal axis parallel to the surface of the leaf.

Of special features it remains to mention: (*a*) sphaerocrystalline masses of unknown chemical composition which have been observed in the epidermis of the leaves (for the most part in herbarium material) in species of the genera *Anagyris*, *Piptanthus*, *Thermopsis*, *Cyclopia*, *Podalyria*, *Chorizema*, *Phyllota*, *Pultenaea*, *Latrobea*, *Eutaxia*, *Dillwynia* (Podalyrieae), and of the genera *Hovea*, *Aspalathus*, *Crotalaria* and *Argyrolobium* (Genisteae); (*b*) small bodies resembling indigo or indican have been found in the mesophyll of the dried leaves in species of *Melolobium*, *Crotalaria* and *Prioritropis* (Tribe Genisteae), in species of *Hymenocarpus*, *Helminthocarpum*, *Lotus* and *Hosackia* (Tribe Loteae), and in species of *Lens* and *Lathyrus* (Tribe Vicieae); (c) lastly, substances resembling saponin occur as shapeless masses in the epidermal cells of species of *Aspalathus* (Tribe Genisteae).

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[1] For the occurrence of sphaerites and clustered crystals in the embryo of the Papilionaceae, see Caldarera, in Atti Accad. Gioenia Sc. nat., ser. 4, vol. xi, 1898 (abstr. in Just, 1898, ii, p. 221); also Lindinger, Diss., 1903, p. 10.

In the Tribes recently investigated the ordinary type of clothing hair is again in the form of uniseriate **trichomes**, consisting of three cells, viz. (*a*) a frequently enlarged epidermal cell, serving as a basal cell; (*b*) a short neck- or stalk-cell, which is occasionally distinguished by having special contents and by being suberized; and (*c*) an elongated terminal cell, of variable character. The terminal cell shows either uniform or unilateral thickening or is provided with a spiral thickening band, which mostly, however, makes only one or two turns; occasionally the terminal cell is band-shaped and twisted, while in *Abrus* it bears a characteristic awn-like process. The longitudinal wall of the end-cell frequently bears verrucose or peg-shaped irregularities, sometimes resembling papillae, e.g. in certain Podalyrieae (species of *Thermopsis* and *Baptisia*), Genisteae (species of *Lupinus*) and Trifolieae (species of *Trigonella*, *Medicago*, *Melilotus* and *Trifolium*). The terminal cell of the trichomes found in *Hosackia puberula*, Benth. and *H. strigosa*, Nutt. is unevenly thickened, the thicker parts of the wall being provided with two or three peg-like protuberances, which project into the lumen of the cell. Socket-like prominences, formed by the subsidiary cells of the hairs, are found in certain Trifolieae (species of *Trifolium*), Loteae (species of *Hymenocarpus*, *Anthyllis*, *Dorycnium*, *Lotus* (especially *Tetragonolobus*) and *Hosackia*) and Vicieae (species of *Cicer*, *Vicia* and *Lathyrus*).

Deviations from the ordinary type of three-celled clothing hairs have been recorded as follows: (*a*) among the Podalyrieae, in the genera *Gompholobium* and *Daviesia*; the former has simple thick-walled trichomes, divided either by a single thin transverse wall, which segments the hair into two equal halves, or by several thin transverse walls; *Daviesia* has unicellular trichomes, which, however, show transitions to the papillae present on the epidermal cells; (*b*) among the Genisteae, in *Bossiaea scolopendria*, Sm., which has uniseriate trichomes, composed of 4–5 relatively short cells; (*c*) among the Trifolieae, in *Ononis*, in which uniseriate trichomes are of general occurrence; they are mostly formed by 4–8 cells of approximately equal length, and are generally narrow and flagelliform, more rarely conical; in all probability, however, they may be derived from the glandular hairs which are found in this genus (regarding this point, see G. Fischer), these hairs having long uniseriate stalks; (*d*) lastly, among the Vicieae, the hairs which are intercalated among the external glands in the extrafloral nectaries of the species of *Vicia*; these hairs consist of a high basal cell and an elongated terminal cell, which has relatively thin walls and is occasionally subdivided by a transverse wall.

A characteristic type of three-celled clothing hairs has recently been observed in the form of trichomes with a distinctly two-armed terminal cell, the arms being of equal or unequal length; these occur in species of *Oxylobium*, *Chorizema*, *Mirbelia*, *Jacksonia*, *Pultenaea* and *Dillwynia* (Tribe Podalyrieae), and in species of *Hovea*, *Lotononis*, *Lebeckia*, *Aspalathus*, *Buchenroedera*, *Crotalaria* (rare), *Genista* (rare), *Calycotome*, *Erinacea* and *Cytisus* (Tribe Genisteae), while the hairs in certain species of *Priestleya*, *Aspalathus* and *Genista* (Tribe Genisteae) only show a tendency to develop this structure.

External glands are of general distribution among the Trifolieae and Vicieae. Among the Genisteae they are found only in *Adenocarpus* and *Melolobium*, and among the Loteae only in *Securigera*, while they are completely wanting in the Podalyrieae. The glandular hairs occurring in the genera *Parochetus*, *Trigonella*, *Medicago*, *Melilotus* pro parte and *Trifolium* (Trifolieae) are small and have short stalks; as a rule they consist of (*a*) a small basal cell, (*b*) a short, uni- or bicellular stalk which is more or less demarcated, and (*c*) an ellipsoidal or club-shaped head, which is elongated to a varying extent and is subdivided by horizontal walls and often by vertical walls as well. On the other hand the glandular hairs found in *Ononis*, and in *Medicago lupulina*, L.,

M. prostrata, Jacq., and *M. scutellata*, All., mostly have long stalks and are visible to the naked eye; the stalk is uniseriate, the component cells showing a gradual decrease in bulk, breadth and thickness of wall towards the upper end, while the multicellular ellipsoidal head is divided by longitudinal and transverse walls; the hairs of this type are accompanied by other external glands which have shorter stalks, but otherwise vary in structure. Among the Vicieae, *Cicer* has glandular hairs which are visible to the naked eye; these trichomes have a long uniseriate stalk composed of 4–6 cells, and a head, which in most cases comprises four multicellular tiers. The remaining Vicieae only have small external glands with a short stalk and a more or less sharply demarcated head, which usually consists of two or more cells and is club-shaped; only in rare cases is the head elongated and tubular (species of *Lathyrus* and *Pisum*), or composed of four cells and peltate, the shield having a lobed margin and showing excentric insertion on the stalk (*Lathyrus hirsutus*, L.). The external glands found in the genus *Adenocarpus* (Genisteae) are confined to the ovary and the fruit: they are multicellular glandular shaggy hairs, columnar in shape and broadened in a capitate manner at their apex. The unicellular glands of *Melolobium* (Tribe Genisteae) consist of a short stalk and a globular head; the base of these hairs is inserted either directly in the epidermis or at the apex of a conical pedestal, composed of parenchyma. The multicellular emergences occurring on the different parts of the axis in the monotypic genus *Securigera* (Loteae) are recognizable with the naked eye; their apex bears a cell containing secretion.

The extrafloral **nectaries** found in the species of *Vicia* are formed by shortly stalked glands intermingled with anomalous forms of clothing hairs; they occur in species of the section *Euvicia* and in *V. bithynica*, L. The honey-secreting organs discovered by Delpino (Malpighia, iii, 1889, p. 345) on the lower side of the leaves in *Glycine sinensis* have not yet been closely examined.

For the structure of the spiny rachis of the leaf of *Halimodendron* and *Caragana*, see Mittmann and Lothelier respectively; for the anatomy of the stipular spines of *Robinia*, see Mittmann. We may add that the anatomy of the spiny stems of *Ononis* is dealt with by Mittmann, that of the stem-spines of *Ulex* and *Genista* by Lothelier, ll. cc.

3. Structure of the Axis. New investigations on the structure of the axis have been published especially by Prenger and Hühner (Podalyrieae [1]), by Schroeder, Cohn, Winkler, Levy, H. Schulze, W. Schulze and Rauth (Genisteae [2]), and by Streicher (Vicieae [3]), ll. cc.

The general features presented by the structure of the **wood** in these Tribes are identical with those which have been previously recorded. To the statements made on pp. 272, 273 regarding the structure of the vessels we may add that sieve-like structure of the bordered pits is found also in species of *Argyrolobium*, *Hypocalyptus* and *Laburnum*, and spiral thickening of the pitted vessels also in species of *Amphithalea, Anagyris, Argyrolobium, Coelidium, Erinacea, Laburnum, Lathriogyne, Lebeckia, Liparia, Lotononis, Petteria, Platylobium* and *Priestleya*. Another noteworthy feature is constituted by the broad medullary rays of the wood in *Lebeckia microphylla*,

[1] Species of *Anagyris, Piptanthus, Thermopsis, Baptisia, Cyclopia, Podalyria, Brachysema, Oxylobium, Chorizema, Mirbelia, Gastrolobium, Pultenaea, Latrobea, Eutaxia, Dillwynia.*

[2] Species of *Liparia, Priestleya, Amphithalea, Lathriogyne, Coelidium, Platylobium, Bossiaea, Templetonia, Hovea, Goodia, Borbonia, Rafnia, Euchlora, Lotononis, Rothia, Lebeckia, Viborgia, Crotalaria, Prioritropis, Aspalathus, Buchenroedera, Melolobium, Dichilus, Heylandia, Lupinus, Argyrolobium, Genista, Adenocarpus, Calycotome, Laburnum, Petteria, Spartium, Erinacea, Ulex, Hypocalyptus, Loddigesia.*

[3] Species of *Cicer* and *Abrus*.

Eckl. et Zeyh.; these rays arise by the fusion of several medullary rays in the outer part of the secondary wood.

To the last paragraph but two on p. 274 we may add, that a tier-like structure of the wood is found also in *Pongamia glabra*, Vent. (Quanjer); to p. 274, last paragraph but one, that according to Saupe the wood quite generally has a very loose texture in the Phaseoleae (also in *Strongylodon*, according to my own observation), the ground-work being formed by thin-walled wood-parenchyma in which groups of wood-fibres are inserted; this structure is what we should expect in view of the fact that the members of this Tribe are lianes.

Regarding the development of the **cork** the following new facts have been published (cf. p. 276).

Epidermal development of the cork is found in species of *Oxylobium* (Tribe Podalyrieae), *Erinacea* and *Loddigesia* (Tribe Genisteae), *Abrus* (Tribe Vicieae), and according to Oberlaender also *Myroxylon*. The cork develops in the first layer of primary cortical cells in species of *Podalyria* and *Gastrolobium* (Tribe Podalyrieae), *Liparia*, *Priestleya*, *Lathriogyne*, *Coelidium*, *Hovea*, *Goodia*, *Lotononis*, *Crotalaria*, *Prioritropis*, *Melolobium*, *Calycotome*, *Spartium* and *Hypocalyptus* (Tribe Genisteae); in the second layer of the primary cortex in species of *Thermopsis*, *Dillwynia* and *Eutaxia* (Tribe Podalyrieae), *Amphithalea* and *Buchenroedera* (Tribe Genisteae); in the second to fourth layer in species of *Pultenaea* (Tribe Podalyrieae), *Argyrolobium* and *Laburnum* (Tribe Genisteae); in the middle of the primary cortex in species of *Anagyris* and *Piptanthus* (Tribe Podalyrieae); in a region of the primary cortex situated near the pericycle in *Cicer* (Tribe Vicieae); in the innermost layer of the primary cortex in *Halimodendron argenteum*, DC. (according to Jönsson). Pericyclic cork-development is found among the Genisteae, also in the genera *Borbonia*, *Lebeckia*, *Viborgia*, *Aspalathus*, *Adenocarpus*, *Petteria* and *Ulex*.

For the development of the cork on the furrowed stems of the leafless Papilionaceae, see the respective papers by Ross, &c., which have already been cited in the earlier part of this work; also Lévy and Roth, loc. cit. At this point we may also refer to the development of a mucilaginous cork in *Halimodendron argenteum*, DC., on the basis of Jönsson's description; the cells formed by the phellogen become rounded off and filled with a mucilaginous substance, which results in their ultimate detachment. Lastly, in a few species of *Oxylobium* (*O. arborescens*, R.Br. and *O. retusum*, R.Br.) Damm met with a 'cuticular epithelium' (see under Loranthaceae), beneath which cork-formation takes place in later stages.

For the structure of the **cortex** in the leafless Podalyrieae and Genisteae and the anatomy of the winged stems, see also the papers by Bürkle, Schroeder, Rauth and Van Tieghem (1905).

The following new facts (see also Pitard, loc. cit.) regarding the nature of the **pericycle** are supplementary to those previously mentioned (on p. 278).

The following genera have isolated groups of bast-fibres: among the Podalyrieae, *Anagyris*, *Piptanthus*, *Thermopsis*, *Baptisia*, *Cyclopia*, *Podalyria*, *Oxylobium*, *Chorizema*, *Mirbelia*, *Gastrolobium*, *Latrobea*, *Eutaxia*, *Dillwynia*; among the Genisteae, *Amphithalea*, *Lathriogyne*, *Coelidium*, *Templetonia*, *Goodia*, *Rafnia*, *Euchlora*, *Lotononis*, *Rothia*, *Lebeckia*, *Viborgia*, *Crotalaria*, *Prioritropis*, *Aspalathus*, *Buchenroedera*, *Melolobium*, *Dichilus*, *Lupinus*, *Argyrolobium*, *Genista*, *Adenocarpus*, *Calycotome*, *Laburnum*, *Petteria*, *Spartium*, *Erinacea*, *Ulex*, *Hypocalyptus*, *Loddigesia*; among the Vicieae, *Cicer*. At certain points between the groups of bast-fibres groups of stone-cells are occasionally found; in *Bossiaea microphylla*, Sm. the isolated groups of bast-fibres become secondarily united to form a continuous strengthening ring owing to the outermost part of the secondary cortex undergoing subsequent sclerosis. A composite and continuous ring of sclerenchyma is present in the pericycle also in species of *Brachysema* and *Pultenaea* (Tribe Podalyrieae), *Liparia*, *Priestleya*, *Platylobium* and *Hovea* (Tribe Genisteae), and *Abrus* (Tribe Vicieae); an almost continuous and composite ring in *Borbonia* (Tribe Genisteae).

It is interesting that the secondary thickening layer (which consists of cellulose), in the fibrous cells constituting the T-shaped groups of bast-fibres found in *Genista*

polygalaefolia, DC. and *G. radiata*, Scop., disappears in later stages, probably as the result of the action of a ferment dissolving cellulose; this thickening-layer is therefore of the nature of reserve-cellulose (see W. Schulze and Rauth, ll. cc.).

Astely occurs in the stem of *Trifolium* (Belli). Cortical vascular bundles are found also in *Borbonia lanceolata*, L. and *Viborgia obcordata*, Thunb. (according to Cohn), as well as in *Genista canariensis*, L., *G. prostrata*, Lam., and *G. sagittalis*, L. (according to Van Tieghem), but by no means in all Papilionaceae with winged stems (see Van Tieghem, loc. cit., 1905).

To the list of **anomalous structural features** found in the axis (p. 279) we may add the occurrence of secondary strands of wood and bast in the primary cortex of *Derris uliginosa*, Benth. (Tribe Dalbergieae), according to Perrédès, and of successive rings of growth in *Mucuna gigantea*, DC., and *Strongylodon* sp. (Tribe Phaseoleae).

The secondary strands of wood and bast in *Derris uliginosa* are found in parts of the axis which are about 1½ cm. or more in thickness. They are present to the number of one or two, and occupy a peculiar position; a band of sclerenchyma, containing pericyclic bast-fibres, is situated on their inner side, while on their outer side there is another sclerenchymatous band, which forms part of the composite and continuous ring of sclerenchyma in the pericycle and contains no bast-fibres. In view of these facts it seems probable that the secondary strands of wood and bast are developed in the primary cortex.—Pieces of the stem of *Mucuna gigantea*, collected by Loher in the Philippines and having a diameter of 4–5 cm., show one or two more or less completely differentiated rings of growth; the first (normal) ring of wood in this species attains a thickness of 7–9 mm. As in the species examined by H. Schenck, the secondary zones of growth originate in the pericyclic parenchyma. Interxylary phloem has not been met with in *M. gigantea*, although it occurs in *M. pruriens* (see H. Schenck, Anatomie der Lianen, p. 164), contrary to the earlier statement on p. 280.—The anomalous structure observed in *Strongylodon* was found in a piece of the stem, 2½ cm. thick, likewise collected by Loher (Montalban, Philippines); an analysis of the flowers present on the corresponding herbarium-material has shown that this stem belongs to the genus *Strongylodon*. The normal ring of wood in this case attains a thickness of 4 mm.; it is followed by two concentric rings of growth, and occasionally the rudiments of a third ring are present. It may be specially pointed out that the secondary rings of wood and bast here apparently arise in the bast of the zone of bundles situated immediately internal to the one in process of development. Regarding the artificial production (by means of wounds) of extrafascicular vascular bundles in *Phaseolus*, see Schilberszky, loc. cit.

II. Caesalpinieae (pp. 281–291).

1. Review of the Anatomical Features. Schizogenous secretory cavities occur also in *Daniella*, *Detarium*, *Kingiodendron*, *Oxystigma* and *Hardwickia*, schizogenous interxylary secretory canals also in *Daniella*, *Kingiodendron*, *Oxystigma* and *Prioria*. Spicular fibres are present in the leaf also in *Oxystigma Mannii*, Harms. Uniseriate clothing hairs with an elongated terminal cell are found in *Scorodophloeus Zenkeri*, Harms.

2. Structure of the Leaf. In the species which I have recently investigated the **epidermal cells** of the leaf exhibit the following characters. Undulated lateral margins with marginal pits and the occurrence of thin vertical walls are distinctive of the species of *Copaifera* pro parte, *Kingiodendron*, *Oxystigma* and *Prioria*. Development of papillae on both sides of the leaf is found in *Hardwickia binata*, Roxb., while in *Detarium senegalense*, Gmel. and *Scorodophloeus Zenkeri*, Harms, the lower side of the leaf bears papillae. The species last named also has gelatinized epidermal cells, stomata with subsidiary cells placed parallel to the pore, and uniseriate clothing hairs with a few short basal cells and an elongated terminal cell.

The following details may be mentioned regarding the secretory organs of *Daniella, Detarium, Hardwickia, Kingiodendron, Oxystigma* and *Prioria*. In *Daniella thurifera*, Benn. and *D. oblonga*, Oliv., according to Guignard, there are more or less elongated secretory cavities (but not canals, as Heckel assumes) situated in the primary cortex, and secretory canals, which are found at the periphery of the pith (although belonging to the wood), and also in the secondary wood. Similarly *Prioria copaifera*, Griseb., which I have examined, possesses (*a*) secretory cavities situated in the primary cortex and more or less elongated in the vertical direction, (*b*) numerous secretory canals in the secondary wood, and (*c*) secretory organs of the nature of canals lying at the periphery of the pith and in its interior; those situated at the margin of the pith may be regarded as belonging to the wood, while those occupying the interior of the pith are at least in part merely secretory cavities, which are very much elongated. According to my own investigation, *Hardwickia binata*, Roxb. has secretory cavities only (situated in the primary cortex and sometimes also in the pith and the parenchymatous pericycle), interxylary secretory canals being absent; *Kingiodendron pinnatum*, Harms has secretory cavities, which are only slightly elongated and are situated in the primary cortex, and interxylary secretory canals with rather wide lumina; in *Oxystigma Mannii*, Harms there are (*a*) secretory cavities of varying length in the primary cortex, (*b*) interxylary secretory canals, and (*c*) intercellular secretory receptacles of the nature of canals, which are found at the margin of the pith and occasionally penetrate into the wood. In *Detarium senegalense*, Gmel. there are secretory cavities in the primary cortex and in the pith, but likewise no interxylary canals. The interxylary secretory canals are developed from the cambium, like those of *Copaifera*; their origin is schizogenous. In all these genera secretory cavities are found also in the mesophyll.—For the secretory canals, cavities and cells of *Eperua falcata*, see Courchet, loc. cit.

The occurrence of an ethereal oil containing sulphur in the cortex of *Scorodophloeus Zenkeri*, Harms, which smells of garlic, is interesting from a systematic-chemical point of view, since an oil of this kind has not previously been demonstrated in any member of the Leguminosae. The oil is present in the cortical parenchyma in the combined form as a glucoside, and is accompanied by a ferment, by the action of which the oil is liberated in the presence of water. The cells containing the ferment are of relatively large size, and their contents assume a deep coloration with Iodine dissolved in Potassium Iodide (Hartwich).

Regarding the occurrence of concentric vascular bundles in the petiole of *Cercis Siliquastrum*, see Bouygues, loc. cit.

3. Structure of the Axis. For the structure of the stem-spines of *Gleditschia*, see Mittmann, loc. cit.[1]

III. Mimoseae (pp. 291–299).

2. Structure of the Leaf. For the stomatal apparatus in the phyllodineous Acacias, see Porsch, loc. cit.; for the structure of the stipular spines of the species of *Acacia*, see Mittmann and Lothelier, ll. cc.

3. Structure of the Axis. Sieve-like pits are found on the walls of the vessels also in *Albizzia Lebbek*, Benth. (Ursprung).

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[1] Ursprung's statement as to the occurrence of bordered pits on the wood-prosenchyma in *Afzelia bijuga*, Gray requires verification.

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[1] The statement as to the occurrence of unicellular clothing hairs in *Adenocarpus* is incorrect (cf. Syst. Anat., p. 268, footnote 2); the same is probably true of the statement that glandular hairs occur in *Spartocytisus nubigenus*. The peltate hairs recorded in *Spartocytisus* are no doubt really two-armed hairs.

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ROSACEAE (pp. 301–310).

2. STRUCTURE OF THE LEAF. Among numerous investigated species of *Rosa* papillose differentiation of the lower **epidermis** has been found only in *R. rugosa*, Thunb. (Parmentier); gelatinization of the inner walls of the epidermal cells is recorded by the same authority in many species of *Rosa* and by Knoblauch in species of *Cliffortia*. In *Acaena adscendens*, Vahl papillae are differentiated both on the upper and lower epidermis (Clauditz); according to Köhne, the lower epidermis is papillose also in *Amelanchier rotundifolia*, Dum.-Cours., *Cotoneaster thymifolia*, Wall., *Prunus Padus*, L., *Pyrus amygdaliformis*, Vill., *Sorbus sambucifolia*, Roem., *Spiraea alpina*, Pall., *S. bella*, Sims., *S. bracteata*, Zab., *S. canescens*, Don, *S. expansa*, Wall., and *S. tristis*, Zab. Hypoderm is present also in *Pygeum Wightianum*; *Photinia Notoniana*, on the other hand, only has an epidermis composed of very large cells (Holtermann). In *Rosa* the **stomata** are confined to the lower side of the leaf (except in *R. berberifolia*, Pall.), and develop according to the Ranunculaceous type. In *Acaena adscendens* the stomata are likewise surrounded by ordinary epidermal cells.

Oxalate of lime. In *Rosa* Parmentier met with sphaerites side by side with clustered and solitary crystals, and Bargagli-Petrucci found silica-bodies in the wood-parenchyma of *Parastemon urophyllus*, DC.

To the statements regarding the **hairy covering** we may add :—Structures resembling stellate hairs and external glands with a head composed of numerous cells occur in *Spiraea sorbifolia*, L. (Theorin). Small external glands with a uniseriate stalk and a head composed of one or two cells are found also in *Geum* and *Potentilla* (Bräutigam). *Cliffortia arborea*, Marloth has Malpighian hairs (Marloth), while *C. falcata*, L. only has ordinary unicellular hairs. Extra-floral nectaries are present in the genus *Griffonia*, a member of the Chryso-balaneae (Mattei).

The **petiole** in many species of *Alchemilla* contains three concentric vascular bundles, each provided with a pith and surrounded by a typical endodermis (' faisceaux concentriques vrais '). The petiole of *Sanguisorba canadensis* includes 8–9 isolated bundles, one of which has the same structure as those of *Alchemilla*, while the remaining bundles are hemiconcentric (' faisceaux hémiconcentriques '), i.e. each of them consists of an arc of wood and bast, which is likewise surrounded by a typical endodermis (Bouygues).

For the structure of the integumental prickles of *Rosa* and *Rubus*, see Mittmann and Lothelier, ll. cc. ; these authorities also discuss the anatomy of the spiny branches of *Crataegus*, *Cydonia*, *Pyrus*, *Pyracantha* and *Prunus* ; regarding the integumental prickles of *Rosa*, see also Duchartre, loc. cit.

3. Structure of the Axis. The **cork** develops in the pericycle also in *Margyrocarpus*, *Cliffortia* and *Polylepis*, which belong to the Poterieae (Bouygues).

Burgerstein's recent investigations on the structure of the **wood** in the Pomeae (see the note on p. 308) and in numerous species of *Prunus* have furnished the following facts. Among the Pomeae distinct spiral thickening of the walls of the vessels is found in *Amelanchier*, *Aronia*, *Chaenomeles*, *Cotoneaster*, *Cydonia*, *Eriobotrya*, *Mespilus*, *Micromeles*, *Photinia*, *Rhaphiolepis*, and *Sorbus*, while the spiral thickening is not well marked in *Hesperomeles*, *Osteomeles* and *Peraphyllum*, and is wanting in *Chamaemeles*, *Crataegus*, *Malus*, *Pyrus*, *Pyracantha*, and *Stranvaesia*. The wood in all the Pomeae contains scattered vessels, and in the course of each annual ring the latter showed a gradual decrease in size. The medullary rays vary from one to three (mostly one or two) cells in breadth ; only in *Mespilus* are they from one to five cells broad. The cells of the medullary rays are rather low in *Chaenomeles*, *Cydonia*, *Mespilus* and *Micromeles*, and relatively high in *Cotoneaster*, *Eriobotrya*, *Hesperomeles*, *Photinia* and *Sorbus*. With reference to the structure of the wood in *Prunus*, we may mention that in all the investigated species the vessels show a spiral thickening band, and that they are either scattered or arranged in annular zones ; in the latter case the zone of vessels belonging to the spring-wood appears as a rather sharply marked ring of relatively large pores.

Regarding the structure of the **cortex** we may add that Pitard records a pericycle, comprising isolated groups of bast-fibres with intervening unlignified bands of parenchyma of varying width, in species of *Amelanchier*, *Cotoneaster*, *Crataegus*, *Eriobotrya*, *Kageneckia*, *Lindleya*, *Osteomeles*, *Photinia*, *Prinsepia*, *Prunus* (sensu latiore), *Pygeum*, *Pyrus* (sensu latiore), *Quillaja*, *Rhaphiolepis*, *Rosa*, *Stranvaesia*, *Stylobasium* and *Vauquelinia*. According to the same authority pericyclic sclerenchyma is completely absent in *Canotia holacantha* and *Pterostemon mexicanus*.

Literature : Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 59 et seq.—Buchenau, Ausscheid. einer kryst. org. Säure im Holzkörper e. Eberesche, Festschr. Ver. f. Naturk., Kassel, 1886, pp. 37–9.—Macchiati, Nettarii estraflor. delle Amygd., Nuovo Giorn. bot. Ital., 1886 pp. 305–7.—Nanke, Dikotyle Holzpfl., Diss., Königsberg, 1886, p. 40.—Keller, Luftwurz., Diss., Heidelberg, 1889, pp. 36, 37.—Mittmann, Pflanzenstacheln, Verh. Ver. Mark Brandenburg, 1889, pp. 41 and 67 et seq.—Barber, Corky excresc., Ann. of Bot., vi, 1892, p. 165.—Duchartre, Aiguillons du *Rosa sericea*, Revue gén. de bot., 1893, pp. 5–11.—Lothelier, Épines, Thèse, Paris, 1893, pp. 17, 36

and 38.—Orth, Anatomie d. Gatt. *Potentilla*, Diss., Kiel, 1893, 33 pp.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—[Bastin, Cherry barks, Americ. Journ. Pharm., 1895, pp. 435 and 595 et seq.]—[Burgerstein, Gatt. d. Pomaceen, Wiener Illustr. Gartenzeit., 1896.]—Knoblauch, Ökolog. Anat. etc., Habilitat.-Schr., Tübingen, 1896, p. 11 et seq.—[Parmentier, Espèces crit. ou lit., Mém. Soc. d'émulation Doubs, 1896, p. 327 et seq. (*Crataegus*).]—Bräutigam, Anat. Charaktere der Rosaceen-Bastarde, Diss., Erlangen, 1897, 56 pp., 3 Tab.—Parmentier, Rech. anat. et taxon. sur les Rosiers, Ann. sc. nat., sér. 8, t. vi, 1897, pp. 1–175, 8 pl.; [see also Comptes rendus, Congrès des Soc. sav., 1898, p. 220.]—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iii, p. 476.—Bunting, Cork tissue in roots of some Rosaceous genera, Contribut. Bot. Lab. of Pennsylvania, ii, 1898, pp. 54–65, pl. x.—Burgerstein, Holzstruktur d. Pomaceen, Sitz.-Ber. Wiener Akad., cvii, Abt. 1, 1898, pp. 8–22; and Xylotomisch-syst. Studien über d. Gatt. d. Pomaceen, Jahresbericht Staatsgymnas. ii, Bezirk Wien, 1898, 35 pp.—Crépin, L'anatomie appliquée à la classificat., Bull. roy. de bot. de Belgique, xxxvii, 1898, pp. 7–15; and Idees d'un anatomiste, etc., loc. cit., pp. 151–201.—Guffroy, *Sorbus* et hybrides, Bull. Soc. bot. de France, 1898, p. 341.—[Kayeriyana, Discoid nectary of Jap. cherry leaves, Bot. Magaz. Tokyo, xii, 1898, pp. 281–4; and Disc-shaped glands in the leaves of *Prunus Pseudocerasus*, loc. cit., xiii, 1899, pp. 316–18.]—Spanjer, Wasserapparate, Bot. Zeit., 1898, i, p. 55.—Boergesen og Paulsen, Veget. dansk.-vestind. Öer, Bot. Tidsskr., xxii, 1898–9, pp. 20, 21 (*Chrysobalanus Icaco*, L.).—Burgerstein, Xylotomie d. Pruneen, Verh. k. k. zoolog.-bot. Gesellsch. Wien, 1899, sep. copy, 5 pp.—Köhne, Papillen u. obers. Spaltöffn., Mitted. deutsch. dendrolog. Gesellsch., 1899, pp. 56, 57.—Macchiati, Nettarii estranuz. del *Prunus Laurocerasus*, Bull. Soc. bot. Ital., 1899, pp. 144–7.—Bouygues, Anat. comp. de la tige et du pétiole des Rubées et Rosées, Act. Soc. Linn. de Bordeaux, lv, 1900, pp. xxxii–xl; Id., Polystélie du genre *Alchemilla*, loc. cit., pp. lviii–lix; Id., Tige et pétiole du *Neurada procumbens*, loc. cit., pp. lix, lx; Id., Périderme de qu. Potériées, loc. cit., pp. xcvi–c; Id., Polystélie part. de *Sanguisorba canadensis*, loc. cit., pp. cxlvii–cxlix.—Paulesco, Struct. anat. des hybrides, Thèse, Genève, 1900, pp. 38 and 64 (*Rosa*, *Sorbus*).—Bouygues, Polystélie, Act. Soc. Linn. Bordeaux, lvi, 1901, pp. xxxv–xl.—Petersen, Vedanatomi, 1901, pp. 58–64.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 65, 66, 68, 97–100.—Bargagli-Petrucci, Concrez. silicee, Malpighia, 1902, p. 26 et seq.; and Legnami, loc. cit., p. 300 (*Parastemon*).—Bouygues, Pétiole, Thèse, Paris, 1902, pp. 55 et seq. and 99.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 46, 47 (*Prunus*).—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, pp. 17–19.—Mardner, Phanerog. Vegetat. d. Kerguelen, Diss., Basel, 1902, pp. 22–5 (*Acaena*).—[Mattei et Rippa, Nettarii estranuz. di alcune Crisobalanee, Bull. Orto bot. Univ. Napoli, i, 1902, pp. 286–91; abstr. in Bot. Centralbl., xcv, p. 580.]—[Armari, Piante della reg. medit., Annali di Bot., i, 1903, p. 17 et seq. (*Poterium*).]—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 55, 56.—Süssenguth, Behaarungsverh. der Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, pp. 27–33.—Theorin, Växttrichom, Arkiv for Bot., iii, n. 5, 1904, p. 16.—Weberbauer, Vegetat. d. Hochanden Perus, in Engler, Bot. Jahrb., xxxvii, 1905, p. 60 et seq.—Marloth, *Cliffortia*, in Engler, Bot. Jahrb., xxxix, 1906, p. 319.—Piccioli, Legnami, Bull. Siena, 1906, pp. 127, 130, 157, 163–5.—Holtermann, Einfluss des Klimas, etc., 1907, p. 119 (*Pygeum*, *Photinia*).—[For additional literature, see p. 1172.)

CROSSOSOMATACEAE.

Two features are important for the **diagnosis of the Order** and in support of the view of a Rosaceous affinity, viz. the presence of typical bordered pits on the wood-prosenchyma, and the occurrence of scalariform perforations (with few bars) or of malformed perforations of the same type in the neighbourhood of the primary wood, side by side with the simple elliptical perforations found in the secondary wood. The stomata are surrounded by several ordinary epidermal cells. Trichomes, oxalate of lime, and internal glands are absent.

The structure of the **leaf** has been examined in *Crossosoma Bigelovii*, Wats. (Parish, n. 10, Colorado) and *C. californicum*, Nutt. (Franceschi, n. 41, Guadalupe)[1]. The leaves in both species show centric structure. Palisade tissue is found on both sides of the leaf, and stomata are present in both upper and lower epidermis. The outer walls of the epidermal cells are strongly thickened. In *C. californicum* the epidermis contains sphaero-crystals, which are insoluble in alcohol, but soluble in Caustic Potash and Eau de Javelle. Peculiar small bodies of a dark colour are frequently found in the palisade tissue in both species; their nature is not known. The larger veins are accompanied by a little sclerenchyma only in *C. Bigelovii*.

The structure of the **axis** could only be investigated in *C. Bigelovii*[1].

[1] I am indebted to Geheimrat Engler for the materials for this investigation.

Regarding the **wood** we may add that: (*a*) the vessels have very small lumina; (*b*) the wood-fibres have thick walls and narrow lumina; (*c*) the medullary rays are narrow, consisting of a single row of cells; and (*d*) the walls of the vessels bear bordered pits in contact with parenchyma of the medullary rays. The pericycle contains isolated bast-fibres. The cork is for the most part composed of cells with thin walls, but also includes uniformly sclerosed cells.

Literature: Engler, Crossosomataceae, in Natürl. Pflanzenfam., Nachtr. zu ii–iv. Teil, 1897, p. 185.

SAXIFRAGACEAE (pp. 310–320).

2 A. Structure of the Leaf. For the water-pores, see also Gardiner, loc. cit.

To the previous remarks on the **hairy covering**, we may add that fimbriate appendages, similar to those present on the staminodes, are found on the foliage-leaves, as well as on the sepals and petals in *Parnassia*; they occur in varying numbers in the different species. Both the epidermis and the subjacent layer of cells participate in the formation of these structures, which do not show any sign of swelling at their ends, although they secrete mucilage in early stages (Dutailly)[1].

The **petiole** of *Saxifraga sarmentosa* resembles that of *Alchemilla* in containing three steles, each of which is surrounded by a typical endodermis. *S. crassifolia* shows similar features. Other species of *Saxifraga*, such as *S. dentata*, *S. hirsuta* and *S. lasiophylla*, have at least one hemiconcentric vascular bundle, enveloped by an endodermis (Bouygues).

3 A. Structure of the Axis. According to Schoute and Jeffrey respectively, polystely is found in the nodes of the stem in *Parnassia palustris*[1]

3 B. Structure of the Axis. The pith in *Ribes rubrum*, *R. Grossularia* &c., contains peculiar cavities; in early stages their place is occupied by relatively large thin-walled cells containing clustered crystals, and the development of the cavities is mainly due to the collapse of these crystal-cells (Kassner). In *Roussea simplex* the primary cortex includes a ring of stone-cells bordering directly on the endodermis. In *Brexia chrysophylla* the pericycle comprises a composite and continuous ring of sclerenchyma, while in other species of *Brexia* the ring is interrupted (Thouvenin and Pitard).

For the structure of the spinous organs found in the species of *Ribes*, see Lothelier and Mittmann.

D. The Anomalous Genus Penthorum (Appendix to p. 319).

The following statements regarding the anatomy of *Penthorum* are based on Van Tieghem's and my own observations. The vegetative and specially the reproductive branches bear glandular shaggy hairs with a multiseriate stalk, merging apically into a more or less distinct secretory head. The inner portion of the primary cortex contains large intercellular spaces. Small groups of bast-fibres are found in the pericycle, but there is no secondary hard bast. The wood is traversed by narrow medullary rays, which are one or two rows of cells in breadth. The vessels of the secondary wood have small lumina and are provided with small bordered pits (also in contact with parenchyma of the medullary rays) and scalariform perforations (with numerous or very numerous bars). The wood-fibres, though thick-walled, have rather wi

[1] For details regarding the structure of the leaf, stem, and root in *Parnassia*, see Van Tieghem, loc. cit.

lumina and bear small but distinct bordered pits. The cells of the pith have cellulose-walls, which subsequently become lignified, especially at the margin of the pith. Oxalate of lime is present in the form of clustered crystals, which occur in the pith and primary cortex, as well as in the mesophyll. The petiole contains an arc-shaped vascular bundle. The leaf is bifacial, the stomata being confined to the lower side. According to Van Tieghem, the vascular system of the root is pentarch, the groups of soft bast being supported by bundles of fibres [1].

Literature: Uhlworm, Entwicklungsgesch. der Trichome, Bot. Zeit., 1873, p. 820.—[Gulliver, Rhaphides in *Hydrangea*, Journ. R. Microsc. Soc. London and Edinburgh, iii, 1880, p. 44; abstr. in Just, 1880, ii, p. 149.]—Höhnel, Gerberinden, Berlin, 1880, p. 108 et seq. (*Weinmannia*).—Gardiner, Water-glands in the leaf of *Saxifraga crustata*, Quart. Journ. Microscop. Sci., xxi, N. S., 1881, pp. 407-14, pl. xxiii.—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 77 et seq.—Kassner, Mark, Diss., Basel, 1884, p. 16.—Mittmann, Pflanzenstacheln, Verh. Ver. Mark Brandenburg, 1889, p. 65.—Thouvenin, Appareil de soutien dans les tiges des Saxifrages, Bull. Soc. bot. de France, 1889, pp. 125-33.—C. de Candolle, Inflor. épiphylles, Mém. Soc. de phys. et d'hist. nat. Genève, 1890, vol. suppl., sep. copy, p. 12 et seq.—J. E. Weiss, Korkbild., Denkschr. bot. Gesellsch. Regensburg, vi, 1890, pp. 61, 62.—Lothelier, Épines, Thèse, Paris, 1893, p. 37.—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskr., xix, 1895, p. 219 et seq.—Hallier, in Natuurkundig Tijdschr. voor Nederl. Indie, 1896, p. 310 et seq.—Van Tieghem, Penthore, Journ. de bot., 1898, pp. 150-4; and Ann. sc. nat., sér. 8, t. ix, 1899, pp. 371-3.—Van Tieghem, Parnassiacées, Journ. de bot., 1899, pp. 326-32.—Bouygues, Mérist. vasc. dans le pétiole, Act. Soc. Linn. Bordeaux, lvi, 1901, p. lvii.—Dutailly, *Parnassia*, Assoc. franç. Ajaccio, 1901: i, 1901, p. 126, and ii, 1902, pp. 457-71.—Petersen, Vedanatomi, 1901, pp. 56, 57.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 70.—Bouygues, Pétiole, These, Paris, 1902, pp. 13, 17, 66, 97 and 107.—Gerhard, Blattanat. v. Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 20, 21 (*Platylophus*).—Schoute, Stelartheorie, 1903, p. 120.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 116.—Freidenfeldt, Anat. Bau der Wurzel, Bibl. bot., Heft 61, 1904, pp. 56-61.—Theorin, Vaxttrichom., Arkiv för Bot., iii, n. 5, 1904, p. 3.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 154-6 (*Brexia*).—Hayek, *Saxifraga* I, Denkschr. Wiener Akad., lxxvii, 1905, pp. 616-22 and Tab. i.—Mahen et Gillot, Ascidies des Saxifrages, Journ. de bot., 1905, p. 33 et seq.—Piccioli, Legnami, Bull. Siena, 1906, pp. 130 and 156.—[For additional literature, see p. 1172.]

CRASSULACEAE (pp. 320-324).

1. Review of the Anatomical Features. Both clothing and glandular hairs of the shaggy type occur in this Order.

2. Structure of the Leaf. Brenner records a two-layered **epidermis** in *Crassula portulacea* and a typical papillose epidermis in *Sedum Hillebrandii*, Fenzl, while according to L. Koch *Sedum dasyphyllum* only has isolated papillae; Brenner states that in *Crassula portulacea* distinct papillae are only developed when the plant is placed in a moist chamber. According to Mardner, the **stomata** in *Tillaea moschata*, DC. have three typical subsidiary cells (contrary to what is found in *T. muscosa*) and are situated principally on the upper side of the leaf. Water-pores, moreover, also occur in this species.

With regard to the differentiation of the **mesophyll**, it may be pointed out that in certain species of *Sedum* and *Sempervivum* the assimilatory cells exhibit a stratified arrangement, while the intercellular spaces are lined by a membrane, which we must regard as the metamorphosed outermost layer of the cell-wall.

The clothing and glandular shaggy **hairs** mentioned above are found in *Sempervivum arachnoideum* and have a biseriate structure. The glandular hairs are short and slightly swollen at the apex. The clothing hairs constitute the cobweb-like covering on the leaves and are much longer; the two rows of

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[1] Van Tieghem's statement (ll. cc.) that such bundles of fibres have as yet been observed only in the aerial roots of parasitic Loranthaceae and not in terrestrial roots is incorrect. The phloem-groups in the tetrarch vascular system of the root of *Vicia faba* are likewise supported by hard bast (see Kny, Wandtafel, lvi, 1884).

cells of which they are composed are not absolutely parallel, but are slightly twisted. The lower part of the body of the trichome in both kinds of hairs consists of long cells, while the cells of the upper part are shorter. In the course of their development the clothing hairs pass through all the stages shown by the glandular shaggy hairs; in a certain stage they even secrete ethereal oil, which functions as a glue joining together the neighbouring hairs; subsequently, as a result of extremely rapid growth in length, the bodies of the hairs become intertwined with one another and in this way the dense hairy felt present on the rosette of leaves is ultimately formed (Dintzel).

Literature: Corda, in Sternberg, Flora der Vorwelt, 1838, Anhang, p. lxii and Tab. A.—[Henri, Knospen, etc., Verh. Ver. f. Rheinlande u. Westfalen, 1850, p. 45; and Wurzelfasern von *Sedum Telephium*, etc., loc. cit., 1860.]—Irmisch, *Sedum maximum*, Bot. Zeit., 1855, p. 249 et seq. and Tab. 2 A.—Schwendener, Mechan. Princip, 1874, p. 148.—[Gardiner, in Quart. Journ. Microsc. Sci., 1881, p. 407 et seq.]—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 79 et seq.—Jost, Zerklüft. einiger Rhiz. u. Wurz., Bot. Zeit., 1890, p. 503 et seq. (*Sedum*).—Matteucci, Placche sugherose, Nuovo Giorn. bot. Ital., 1897, p. 236 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl. 1897, iii, p. 475.—Rödler, Assimilator. Gewebesyst., Diss., Freiburg i. Schw., 1898–9, p. 38.—Brenner, Fettpflanzen, Flora, 1900, pp. 389–98.—Schleichert, Xerophyten bei Jena, Naturwiss. Wochenschr., 1900, p. 450 (*Sedum*).—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 41, 42 (*Sempervivum*).—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 20.—Mardner, Phan.-Vegetat. d. Kerguelen, Diss., Basel, 1902, pp. 26, 27 (*Tillaea*).—[Armari, Piante della reg. medit., Annali di Bot., i, 1903, p. 17 et seq. (*Sedum*).]—Dintzel, Haare a. d. Blattsp. von *Sempervivum arachnoideum*, Österreich. bot. Zeitschr., 1905, p. 254 et seq. and Tab. v, vi.

DROSERACEAE (pp. 324–328).

The tentacular glands of *Roridula Gorgonias*, Planch., which have recently been examined by Fenner, are of different lengths; they have a multiseriate stalk, which exhibits corresponding variation in length, and an ellipsoidal head, in which the inner part is formed by a group of approximately isodiametric cells, constituting a continuation of the cells of the stalk, while the secretory epidermis is differentiated like a palisade; tracheids are wanting alike in the stalk and in the head. The middle layer in the digestive glands of *Aldrovanda* consists of two rather high cells, which form a stalk; the number of central and peripheral cells in the glandular disc is occasionally greater than 4 and 8 (viz. 5–8, and 9–14). Pores are present in the cuticle on the secretory heads of *Drosophyllum* and *Drosera rotundifolia* (Haberlandt and Fenner). The genus *Byblis*, which up to the present has been included among the Droseraceae, but which has been transferred, and no doubt rightly so, to the Lentibularieae by Lang, has digestive glands, which differ considerably from those of other Droseraceae; according to Lang, their structure is analogous to that of the glands occurring in the genus *Pinguicula* (Lentibularieae). Both sessile and long-stalked glands are found in *Byblis*. The simplest type of the former consists of three cells, viz. a basal, a median, and a terminal cell; in many cases, however, the terminal cell undergoes division into quadrants followed by the appearance of four anticlinal walls, so that a disc-shaped glandular body is developed, which for the most part consists of eight cells; the basal cell at the same time divides into two cells. In the formation of the long-stalked glands the basal cell divides into two cells by means of a transverse wall, and the upper of these cells grows out into a long unicellular stalk, while the (lower) sister-cell undergoes further division; the terminal cell becomes segmented to form a glandular disc, composed of 16 or 32 cells. The cuticle of the glandular disc, both in the short- and long-stalked glands, bears a pore on the upper and lower side of each cell. A feature deserving special mention is that the glands on the leaf of *Byblis* are associated with the stomata to form parallel longitudinal rows which are sunk below the surface and alternate

with one to three rows of cells, containing neither stomata nor glands. For further details regarding the glands, see the papers by Lang and Fenner, ll. cc. Regarding the tentacular glands of *Drosera* we may add that the epidermal cells of the head are provided with marginal pits which are occupied by protoplasmic processes; these constitute the perceptive organs for the mechanical stimuli, to which the movements of the tentacular glands are due (Haberlandt).

The two- and four-armed glands of *Aldrovanda*, which were discussed under the heading of 'other types of hairs,' have two basal cells and a stalk, consisting of a single layer of two to four cells (Fenner). For details as to the structure of the sensitive bristles of *Aldrovanda* and *Dionaea*, see especially Haberlandt, loc. cit.

Although the **stomata** of the Droseraceae were previously stated not to have any subsidiary cells (p. 326), it has since been shown that in the genus *Byblis*, which Bentham and Hooker place among the Droseraceae, the pair of guard-cells has a single subsidiary cell on each side of the stoma and parallel to the pore (Lang).

As regards the detailed anatomical features of the **leaf** of *Drosophyllum* we may add that the mesophyll is composed of spongy parenchyma with large lacunae; the cells of this tissue contain numerous acicular crystals, which are soluble in a solution of chloral hydrate, as well as a few large crystals of oxalate of lime (A. Meyer and Dewèvre).—According to Lang, the epidermal cells in the leaf of *Byblis* are elongated in the direction of elongation of the leaf. The subsidiary cells of the stomata have already been referred to above. The epidermis is followed by a sheath of two or three layers of cells which show a slight palisade-like differentiation; on the inner side of this zone lies a starch-sheath, and within this again a medulla consisting of cells with wide lumina and enclosing 3–5 collateral vascular bundles; the phloem-groups in these bundles are surrounded on all sides by a sclerenchymatous sheath. The swollen apex of the leaf of *Byblis* contains only a single vascular bundle, which is apparently concentric (with central phloem), and is enveloped by a tissue serving for the storage of water; the walls of this tissue bear pits having a faint border or exhibit spiral to reticulate striation; on its outer side lies a starch-sheath, followed by two or three layers of rounded assimilatory cells. The tip of the leaf bears a few elevated water-pores, but there is no epithema on their inner side (Lang).—The following details regarding the structure of the leaves of *Roridula*, the upper surface of which is furrowed, are based on Fenner's statements. The mesophyll is composed of loose spongy tissue, the lower portion containing large lacunae. The vascular bundles of the veins are supported by groups of sclerenchyma. The stomata are confined to the lower side of the leaf.

The vessels in *Byblis* have simple perforations (Lang). Astely is found only in the peduncle of *Byblis* (Lang).

The structure of the **root** of *Byblis* is normal, the vascular system being triarch.

Literature: Groenland, Org. gland. du genre *Drosera*, Ann. sc. nat., sér. 4, t. iii, 1855, pp. 297–303, and pl. 9.—Trécul, Gl. pédic. du *Drosera rotundifolia*, Ann. sc. nat., sér. 4, t. iii, 1855, pp. 303–11.—A. Meyer and Dewèvre, *Drosophyllum lusitanicum*, Bot. Centralbl., 1894, iv, pp. 33–41.—Macfarlane, Hybrids, &c., Contribut. Bot. Laborat. Pennsylv., ii, n. 1, 1898, p. 87 et seq. and pl. xii. —[Rosenberg, *Drosera rotundifolia*, Medd. Stockh. Högskol. Bot. Inst., ii, 1899, 126 pp., 2 Tab.; abstr. in Just, 1899, ii, p. 207.]—Haberlandt, Sinnesorgane, 1901, p. 94 et seq.—Lang, *Polypompholyx* u. *Byblis gigantea*, Flora, 1901, pp. 179–92; also Diss., Munich.—Dutailly, *Parnassia*, Assoc. franç. Ajaccio, 1901; ii, 1902, pp. 471, 472.—[Hamilton, *Byblis gigantea*, Proceed. Linn. Soc. New South Wales, 1903, p. 680 et seq.; abstr. in Bot. Centralbl., xcvi, p. 579.]—Schoute, Stelärtheorie, 1903, p. 117.—Fenner, Laubbl. u. Drüsen einiger Insektivoren, Diss., Zürich, 1904, pp. 33–91 and Tab. xi–xxi; also in Flora, 1904.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 61 and 63.—Diels, Droseraceae, in Pflanzenreich, Heft 26, 1906, p. 4 et seq.—[Haberlandt, Sinnesorg., 2nd edit., 1906.]

HAMAMELIDEAE (pp. 328–333).

The **petiole** of *Liquidambar* contains three vascular systems of the nature of steles (Bouygues).

Literature: [Höhnel, Kork, Sitz.-Ber. Wiener Akad., lxxvi, Abt. 1, 1877, p. 603.]—Gregory, Cork wings, Bot. Gazette, 1888, pp. 282–7 and pl. xxii (*Liquidambar styraciflua*).—Jadin, Org. sécrét., Thèse, Montpellier, 1888, p. 48 et seq.—Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 51, 52.—[Wassnjewsky, *Parrotia persica*, 1891 (Russian); abstr. in Just, 1893, i, p. 580.] —[Mohr, Balsam von *Liquidambar*, Pharm. Rundschau, N. Y., 1895, xiii, n. 3.]—[Jensen, Rinde von *Hamamelis virginiana*, Pharm. Archiv, 1901, n. 7; abstr. in Just, 1901, ii, p. 58.]—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 102.—Bouygues, Pétiole, Thèse, Bordeaux, 1902, p. 69.—[Kramer, Mikr.-pharm. Beitr., Diss., Würzburg, 1907, p. 20 (*Hamamelis*).]—For *Cercidiphyllum* and other genera belonging to the Hamamelideae, see under Trochodendraceae.

BRUNIACEAE (pp. 333–335).

1. Review of the Anatomical Features. According to Kirchner, the apex of the leaf in all the Bruniaceae is suberized in a peculiar manner.

2. Structure of the Leaf. According to Colozza, the earlier statement that the leaves of the Bruniaceae are traversed by three veins, is only partly correct. In certain species of *Audouinia, Berzelia, Linconia, Pseudobaeckea* and *Staavia* five veins are found, while some of the species of *Pseudobaeckea* have even more (9, 13, or 20).

The **stomata**, as already previously mentioned, are generally present on both sides of the leaf. On the basis of recent investigations the following facts may be added regarding their distribution. In the pinoid, patent leaves of *Linconia cuspidata*, Sw. and the thin flat leaves of *Pseudobaeckea cordata*, Niedenzu the stomata are confined to the lower side. In the broad scaly leaves found in certain species of *Brunia, Lonchostoma*[1], *Pseudobaeckea* and *Raspalia*[2] the stomata occur only on the upper side, which is adpressed to the stem. In certain species of *Brunia* and *Diberara* with subulate inflexed leaves the stomata are practically restricted to the upper side, since stomata are found on the lower side only at the base of the leaf, i.e. on that part of the leaf which is covered by the tips of the leaves below (Kirchner). In *Linconia cuspidata, Pseudobaeckea cordata*[3] and *Thamnea gracilis*, Oliv. Colozza states that the stomata are confined to the lower side, while in *Lonchostoma acutiflorum*, Wickstr., *Pseudobaeckea virgata*, Niedenzu, and *Raspalia phylicoides*, Niedenzu they occur only on the upper side. With reference to the arrangement of the stomata on the surfaces of the leaves, we may mention that according to Kirchner they are irregularly scattered in *Staavia nuda*, Eckl. et Zeyh. and *Brunia sacculata*, Bolus, while in *Staavia capitella*, Sond. and *Brunia palustris*, Schlecht., as well as in *Staavia radiata*, they show a marked transverse arrangement.

According to Colozza, the structure of the leaf is either centric or bifacial, or exhibits transitions between the two types. According to the same authority, the earlier statement that the **palisade-tissue** in all cases consists of a single layer of cells is incorrect. Kirchner states that the palisade-cells are almost invariably placed obliquely to the surface of the leaf. In those leaves in

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[1] Regarding *Lonchostoma*, which in recent times has been referred to the Bruniaceae by general consent, see also the former appendix to the Solanaceae, pp. 581, 582.

[2] According to Kirchner (loc. cit., p. 15) these species are: '*Brunia palustris*, Schlecht.,' '*B. sacculata*, Bolus;' *Lonchostoma acutiflorum*, Wickstr., *L. monostyle*, Sond., *L. obtusiflorum*, Wickstr.; *Pseudobaeckea squalida*, Niedenzu, *P. virgata*, Niedenzu; *Raspalia angulata*, E. Mey, *R. Dregeana*, Niedenzu, *R. microphylla*, Brongn., *R. phylicoidea*, Niedenzu.

[3] See Colozza, loc. cit. p. 20 (in contradiction, however, to the statement on p. 29).

which the upper surface is adpressed to the stem, the palisade-tissue is naturally confined to the lower side of the leaf.

Colozza records solitary crystals of **oxalate of lime** in the neighbourhood of the mechanical sheaths enveloping the vascular bundles of the veins in *Brunia nodiflora*, L. and in the genera *Audouinia*, *Berzelia*, *Diberara*, *Thamnea* and *Tittmannia*; the same authority mentions the occurrence of clustered crystals in the mesophyll in *Brunia globosa*, Thunb. and *B. laevis*, Thunb., and in the genera *Linconia*, *Lonchostoma*, *Pseudobaeckea* and *Staavia*. In *Raspalia* both solitary and clustered crystals are wanting.

Long unicellular clothing **hairs** are recorded by Colozza in species of *Brunia*, *Diberara*, *Pseudobaeckea* and *Raspalia*.

Parenchymatous cells serving for water-storage are present at the apex of the leaf in the neighbourhood of the terminations of the veins; in an unnamed species of *Brunia* similar cells lie scattered in the spongy tissue.

The tip of the leaf in the Bruniaceae is formed by a cap of tissue, composed of brown suberized cells; on the inner side of this cap lies a meristem, from which new cork-cells are produced at the same rate as the outermost ones become exfoliated.

Literature: Knoblauch, Ökolog. Anatomie, etc., Habilitat.-Schr., Tubingen, 1896, p. 15 et seq. —Kirchner, Beitr. z. Kenntnis der Bruniac., Diss., Breslau, 1904, 29 pp.—Colozza, Bruniaceae, Ann. di Bot., ii, Roma, 1905, sep. copy, especially pp. 9–30.

HALORAGEAE (pp. 335–339).

To the first paragraph on p. 335, in which the most **important anatomical features** of the Order are summarized, we may add the following details. The Haloragoideae, Schindl.[1] are distinguished by having uniseriate clothing hairs, the Gunneroideae, Schindl. by having unicellular hairs. The genera *Callitriche* and *Hippuris* are characterized by the possession of peltate hairs; Schindler advocates the exclusion of these genera from the Halorageae, and in this he is probably right. *Hippuris* is also peculiar in the absence of clustered crystals of oxalate of lime. The axis of *Loudonia* is distinguished by having subepidermal groups of sclerenchyma consisting of a single layer of fibres.

Recent investigations have shown that the **mesophyll** rarely contains typical palisade-tissue with marked elongation of its cells; a distinct differentiation into palisade and spongy tissue is found in *Haloragis elata*, Cunn. and in *Loudonia*. Sclerenchymatous elements are completely absent in the leaf. Schindler also states that the **stomata** in no case have characteristic subsidiary cells; we should mention, however, that in the Haloragoideae those walls of the surrounding epidermal cells which converge on the guard-cells are thin, while in the Gunneroideae the contour-walls of the guard-cells themselves are thin; the remaining epidermal cells in both cases have thick lateral walls. As a rule the stomata are present on both sides of the leaf. In the extreme terrestrial species of *Haloragis* and *Loudonia* the stomata situated on the upper side are not so large as those on the lower, and occur in smaller numbers; in other cases they are only represented by rudiments.

Special internal secretory organs are absent, but tannin is widely distributed both in the land- and water-forms. The clustered crystals of **oxalate of lime** are mostly of small size, but very large ones are also found (e.g. in *Gunnera*). They are invariably composed of a large number of individual

[1] Schindler, on whose work the following additions are chiefly based, subdivides the Order as follows: I. Haloragoideae: 1, Halorageae: *Loudonia*, *Haloragis* (incl. *Meionectes*), *Mezialla*, *Laurembergia* (*Serpicula*), *Proserpinaca*; 2, Myriophylleae: *Myriophyllum*. II. Gunneroideae: *Gunnera*.

crystals with very narrow tips. According to Schindler, hair-like cells containing clustered crystals, which were previously mentioned as occurring in the cortex of the stem in *Myriophyllum* and *Serpicula repens*, are found in all the species of *Laurembergia, Meziella, Myriophyllum* and *Proserpinaca*, as well as in certain species of *Haloragis*, having relatively large intercellular spaces. It remains to mention the occurrence of aggregates of acicular crystals, composed of an unknown chemical substance, in *Gunnera Hamiltonii* (according to Schnegg).

We have next to discuss the **trichomes**, and will deal first with the clothing hairs. We have already stated above that according to Schindler uniseriate clothing hairs are characteristic of the Haloragoideae, and unicellular hairs of the Gunneroideae. It should be noted, however, that the aquatic forms (*Myriophyllum* and *Meziella*) have no clothing hairs whatsoever, and that in some species of *Haloragis* unicellular hairs are also found. The latter are, however, connected by transitional forms with the epidermal papillae, which are of frequent occurrence in *Haloragis*, and differ very essentially from the hairs of *Gunnera* (which have thin walls and wide lumina) in being of small size and having thick walls and narrow lumina. The unicellular trichomes of the New Zealand species of *Gunnera* examined by Schnegg are for the most part club-shaped and crowned by a short awn. According to Schindler, the distinction between *Hippuris maritima* and *H. vulgaris* (mentioned in the earlier part of this work) based on the structure of the rays of the peltate hairs cannot be maintained.

According to Schindler, glandular shaggy hairs, having the same structure as those of *Myriophyllum* and *Gunnera*, occur in all the Haloragoideae with the exception of *Loudonia*; they are situated in the excavations on the leaf-teeth, &c., and are visible even with a lens as small lappets or dots. Other forms of hairs to be mentioned here are: (1) the soft cylindrical hairs of *Gunnera*, which had already previously been observed by Uhlworm, and consist of four regular rows of cells; (2) the emergences recorded by Schindler in *Haloragis exalata*, F. v. M., and occurring on the axes in the form of coarse knobs having the shape of an inverted flask; and (3) the multicellular trichomes described by the same author in certain terrestrial species of *Haloragis* (*H. confertifolia*, F. v. M., *H. elata*, Cunn., and *H. exalata*, F. v. M.); these trichomes resemble a blackberry in form and are purely epidermal structures.

In turning our attention to the structure of the **axis** we may once more emphasize the absence of intraxylary phloem in view of the close affinity of this Order with the Onagrarieae. According to Schindler, Parmentier's statements as to the occurrence of internal soft bast in *Haloragis* and *Loudonia* (cf. footnote 1 on p. 335) are incorrect. Schindler states that the vessels have simple perforations in all the members of the Order. Among the features presented by the cortex (cf. p. 339) the occurrence of subepidermal groups of sclerenchymatous fibres in *Loudonia* has already been referred to above. Most of the Haloragoideae are characterized by having very large air-cavities in the primary cortex, the cavities being arranged to form a single ring (except in *Haloragis salsoloides*, Benth.). These intercellular spaces are most prominent in the aquatic forms, but are also found in the large majority of terrestrial species of *Haloragis*, although not so strongly developed. They are absent, however, in *Loudonia*, *Haloragis foliosa*, Benth., *H. Gossei*, F. v. M. and *H. pycnostachya*, F. v. M. In many Halorageae (sensu Schindler) intercellular spaces are present in the pith as well, but they are wanting in *Meziella*, as well as in the Myriophylleae (*Myriophyllum*). In contrast to the typical Halorageae, *Hippuris* has several layers of intercellular spaces in the cortex; the same applies to *Haloragis salsoloides*, Benth., a species already referred to above.

A brief description of the vascular system of the petiole and stolons in the species of *Gunnera*, examined by Schnegg, may be given, the reader being referred for details to Schnegg's paper. The larger petiolar strands are distinct steles; in the simplest case (e.g. *G. dentata*) they consist of a concentric vascular bundle, surrounded by an endodermis and provided with central xylem, the innermost vessels of which are situated in an apparent pith and exhibit compression; in *G. lobata* the steles include a pith composed of sclerenchymatous fibres and have a collenchymatous sheath; a still higher degree of differentiation is attained in *G. magellanica*, in which the place of the pith is taken by a vascular system, supported by two groups of sclerenchymatous fibres and composed of central strands of phloem with peripheral xylem-vessels, while the collenchyma-sheath is accompanied by a second sheath, provided with Caspary's dots on its radial walls. The stolons, with some few modifications, as a rule show two rings of wood and bast, the inner one of which is inversely orientated as regards the position of xylem and phloem; in *G. Hamiltonii* there is only a single stele, while in *G. chilensis* there are several (3–7).

Literature: Uhlworm, Entwicklungsgesch. d. Trichome, Bot. Zeit., 1873, pp. 769–73 and Tab. ix; also Diss., Leipzig.—Costantin, Tiges de pl. aquat., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 and pl. xiv, xv.—[Danielli, Certi org. della *Gunnera scabra*, Atti Soc. Tosc. Sc. Nat., vii, 1885, 17 pp.; abstr. in Bot. Centralbl., 1885, iii, p. 303.]—Scott, Polystely, Ann. of Bot., v, 1890–91, p. 514 et seq.—[Parmentier, in Le Monde des Pl., 1897, p. 178 et seq.]—Weinrowsky, Scheitelöffn. bei Wasserpfl., Diss., Berlin, 1898, p. 24.—Roedler, Assimilator. Gewebesyst., Diss., Freiburg i. d. Schw., 1898–9, p. 34 et seq.—Minden, Wassersec. Organe, Bibl. bot., Heft 46, 1899, p. 20 (*Callitriche*).—Perrot, Org. app. des feuilles de cert. *Myriophyllum*, Journ. de Bot., 1900, pp. 198–202.—W. B. Mc.Callum, *Proserpinaca palustris*, Bot. Gaz., 1902, pp. 93–108.—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 20.—[Porsch, Spaltöffnungsapp. submers. Pflanzenteile, Sitz.-Ber. Wiener Akad., cxii, Abt. 1, 1903, pp. 103–7 (*Callitriche, Hippuris*)].—Schnegg, Beitr. z. Kenntnis d. Gatt. *Gunnera*, Flora, xc, 1902, p. 161 et seq.; also Diss., Munich.—Schoute, Stelartheorie, 1903, pp. 121–2.—Schindler, Abtr. d. Hippuridaceen von den Halorag., in Engler, Bot. Jahrb., xxxiv, 1904, Beibl. 77, 77 pp., especially pp. 53–69 and 74–5; also Diss., Erlangen.—Günther, Anat. d. Myrtifloren, Diss., Breslau, 1905, p. 27 et seq.—Schindler, Halorrhagaceae, in Pflanzenreich, Heft 23, 1905, pp. 5–9.—Géneau de la Lamarliere, Membr. cut. d. pl. aquat., Revue gén. de Bot., 1906, p. 289 et seq.

RHIZOPHORACEAE (pp. 339–343).

2. Structure of the Leaf. The following additional facts have become known. The outer appendicular ridges on the stomata of *Ceriops Candolleana*, Arn., *Bruguiera gymnorhiza*, Lam., and *Rhizophora mucronata*, Lam. are split into two, so that the front cavity is divided into two parts. An aqueous tissue belonging to the spongy parenchyma is found also in the interior of the mesophyll of *Kandelia* and *Bruguiera*. The palisade-tissue of *Rhizophora* consists of a layer of very much elongated cells, which exhibit more or less abundant transverse divisions. Lastly, according to Areschoug's statements, hypoderm occurs on the lower side of the leaf more frequently than was previously stated.

3. Structure of the Axis. According to Pitard, the pericycle in *Rhizophora Mangle* and *Bruguiera parviflora* contains only isolated groups of bast-fibres; sclerosed stone-cells, which are occasionally branched, are found in their neighbourhood.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 129 et seq.—[Karsten, Mangrovevegetat., Bibl. bot., Heft 22, 1891.]—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 73.—Areschoug, Blattbau d. Mangrovepfl., Bibl. bot., Heft 56, 1902, pp. 42, 57 and 66 et seq., Tab. i–iii, ix and xiii.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 354 (*Bruguiera*).—Holtermann, Anat.-physiol. Untersuch., Sitz.-Ber. Berliner Akad., 1902, i, p. 671.—[Blatter, Mangrove of the Bombay Presidency, Journ. Bombay Nat. Hist. Soc., xvi, 1905, pp. 644–56 and pl.]—Günther, Anat. d. Myrtifloren, Diss., Breslau, 1905, p. 25.—Gürtler, Interzellulare Haarbild., Diss., Berlin, 1905, p. 40.—Poulsen, Stötterødderne hos *Rhizophora*, Vidensk. Meddelels. Kjøbenhavn, 1905, pp. 153–64 and Tab. v.—Holtermann, Einfluss d. Klimas, etc., 1907, pp. 30, 57, 60 and Tab. ix (*Bruguiera*, *Ceriops*, *Rhizophora*).

COMBRETACEAE (pp. 343–350).

2. Structure of the Leaf. The absence of a typical hypoderm is remarkable. Aqueous tissue is present in the middle of the mesophyll in *Laguncularia racemosa*, as well as in *Lumnitzera coccinea* and *L. racemosa* (Holtermann). We may also mention, likewise on Holtermann's authority, the occurrence of large terminal tracheids in *Laguncularia racemosa*, and of hydathodes provided with an epithema in species of *Laguncularia* and *Lumnitzera*. To the previous account of the **hairy covering** we may add that cap-shaped glandular hairs, similar to those found in *Laguncularia racemosa*, occur also in *Conocarpus erectus*, though the hairs of this species are far less sunk, and consist of a smaller number of cells (Boergesen and Paulsen). Details as to the differentiation of the shield in the peltate glands of certain African species of *Combretum* are given by Engler and Diels, loc. cit. According to Boergesen and Paulsen, special epidermal idioblasts occur on both surfaces of the leaf, but mainly on the upper side, in *Conocarpus erectus* (hydathodes ??); they are distinguished from the remaining epidermal cells by their rounded outline and by the presence of a conical elevation arising from the middle of the cell; this protuberance has a striated cuticle, and often includes a small space which is separated from the rest of the lumen of the cell. The petiolar glands of *Conocarpus erectus* constitute two depressions on the upper side of the petiole, and are provided with an epithema and the termination of a vascular bundle (Areschoug); regarding the glandular stipules found in species of *Combretum*, see Mirabella, loc. cit.

For the structure of the petiolar **spines** of *Combretum*, see Heiden, Holmes, and Lefèvre, ll. cc.

3. Structure of the Axis. The **interxylary phloem** in the specimen of *Combretum salicifolium*, E. Mey (cf. Holtermann's statement on p. 350), examined by Leisering, develops in the same way as in *Guiera*. According to Lefèvre, the same mode of development also obtains in *Combretum glutinosum*, Guill. et. Perr.

Phelloid-cells have been demonstrated in the **cork** of *Quisqualis* (J. E. Weiss). Lefèvre states that the cork develops sub-epidermally in *Conocarpus leiocarpus*, DC. (= *Anogeissus leiocarpus*, Guill. et Perr.) and *Anogeissus pendula*, Edgew.

According to Lefèvre, intercellular **mucilage-spaces** of schizogenous origin similar to those present in the veins of the leaf occur also in the intraxylary phloem of *Terminalia Bellerica*, Roxb., *T. procera*, Roxb. and *T. tomentosa*, W. et A., as well as in the interxylary phloem of *Combretum glutinosum*, Guill. et Perr.

According to Karsten, the negatively geotropic respiratory **roots** *of Lumnitzera racemosa*, Willd. exhibit a well differentiated system of intercellular spaces in the secondary cortex in later stages. This intercellular system is specially distinguished by its mode of development. In the first place the cells commence to separate from one another at certain points and especially at the corners, so that they only remain connected by narrow processes; in this way the tissue acquires the appearance of a parenchyma the cells of which are provided with numerous processes emanating in all directions ('conjugate parenchyma'). The intercellular spaces gradually increase in size, and the connecting processes become longer; division-walls appear in the latter and thus a strongly developed system of intercellular spaces is ultimately formed. According to Boergesen and Paulsen, the intercellular spaces in the primary cortex of the 'asparagus-like roots' of *Laguncularia racemosa*, Gaertn. f. develop in exactly the same way.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 127 et seq.—Höhnel, Neue Gerbebl., in Dingler, Polytechn. Journal, ccxl, 1881, pp. 388–91.—J. E. Weiss, Korkbild., Denkschr. bot.

Gesellsch. Regensburg, vi, 1890, sep. copy, p. 16.—Karsten, Mangrovevegetat., Bibl. bot., Heft 22, 1891, pp. 51–2 and Tab. ix.—Brandt, Wenig bek. Rinden, Diss., Dorpat, 1894, p. 30 et seq.—[Mirabella, Colleteri, Contribuz. Ist. Bot. Palermo, ii, 1897, p. 15 et seq.; abstr. in Just, 1897, p. 513.]—Boergesen og Paulsen, Vegetat. dansk. vestind. Öer, Bot. Tidsskrift, xxii, 1898–9, pp. 43–8 (*Laguncularia racemosa*, Gaertn. f.) and pp. 52–4 (*Conocarpus erectus*, L.).—Areschoug, Blattbau der Mangrovepfl., Bibl. bot., Heft 56, 1899, pp. 71–7 and Tab. ix–xiii.—Engler and Diels, *Combretum*, in Engler, Monogr. afrikan. Pflanzenfamilien u. Gatt., iii, 1899.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 14–17.—Baranetzky, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xii, 1900, p. 300.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 356 (*Lumnitzera*).—Penzig, Piante acarofile, Malpighia, 1902, p. 446 et seq. (*Terminalia*).—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 15, 16 and 75 (*Combretum*), pp. 94, 95 (*Terminalia*), pp. 115–16 (*Quisqualis*).—Günther, Anat. d. Myrtifloren, Diss., Breslau, 1905, pp. 25, 26.—Lefèvre, Ét. anat. et pharmacol. des Combret., 1905, in Perrot, Travaux, iii, 1906, 126 pp.—[Drabble, Anat. of the Kinkeliba, *Combretum Raimbaulti*, Quart. Journ. Comm. Research in the Tropics, Liverpool, ii, 1907, pp. 66–70, 1 pl.]—Holtermann, Einfluss des Klimas, etc., 1907, pp. 32, 55, 58, 59 (*Laguncularia*, *Lumnitzera*).

MYRTACEAE (pp. 350–358).

1. Review of the Anatomical Features. The unicellular clothing hairs found in certain members of the Myrtaceae sens. str. are two-chambered in the same way as in the Combretaceae. Unicellular Malpighian hairs, showing transitions to ordinary unicellular trichomes, are found also in *Eugenia correaefolia*, Hook. et Arn. The hairs of *Bertholettia excelsa*, Humb. et Bonpl., exhibit a tendency towards a tufted arrangement, while those of *Lecythopsis rufescens* show indications of branching. Shaggy hairs are present in *Lhotskya genethylloides*, F. v. M.

Among the **anomalous genera** (see p. 351) *Gaslondia* and *Psiloxylum* have recently been investigated by Van Tieghem. Both of them have proved to be members of this Order, as evidenced by the presence of secretory cavities in the primary cortex and mesophyll, and by the occurrence of intraxylary soft bast. Of the remaining anatomical features of the two genera we may mention the following. The cork in *Gaslondia* develops in the second cortical layer and is composed of alternating strata of quadrangular thin-walled cells and flat lignified cells, whilst in *Psiloxylum* it arises in the pericycle and consists of layers of flat thin-walled cells and thickened cells with wider lumina. The pericycle in *Gaslondia* contains isolated groups of hard bast, and the phloem is stratified into hard and soft bast, while in *Psiloxylum* bast-fibres are completely absent, and the stratification of the phloem, as in 'Cortex Granati,' is due to cells containing clustered crystals. In both genera, lastly, the stomata are found only on the lower side of the leaf; the palisade-tissue in *Gaslondia* includes relatively large cells with clustered crystals.

A. Myrtaceae sens. str. (pp. 352–355).

Holtermann records remarkably large epidermal cells in *Eugenia subavenis*, and stone-cells in the mesophyll in *E. rotundifolia* and *E. sclerophylla*.

I have myself investigated the **hairy covering**, and may mention in the first place that some of the simple unicellular clothing hairs are two-chambered, like those found in the Combretaceae. As in that Order the basal portion of the hair contains a body which varies in length and has the appearance of a cell, and in this way the duplication of the hair is brought about. This feature is found: (*a*) in the narrow, elongated clothing hairs of *Leptospermum grandifolium*, Hort., which have thick walls and narrow lumina and give rise to the silky covering on the leaves; (*b*) in the short curly clothing hairs on the leaves of *Metrosideros tomentosa*, A. Rich.; (*c*) in the similar hairs of *Kunzea ericifolia*, Reichb.; (*d*) in the mostly one-armed hairs on the leaves of *Psidium Guajava*, L.; (*e*) lastly also in the hairs on the fruits of the Pimento (belonging to *Pimenta officinalis*, Lindl.; in this case they are figured by Rosen on his 'Wandtafel,' xxvi, Fig. *B* and *C*, but are not considered in the corresponding

text, p. 188); these **hairs** are one-armed or indistinctly two-armed with arms of unequal length. On the other hand, the unicellular clothing hairs found on the ovary of *Pileanthus filifolius*, Meissn. do not show the two chambers. Unicellular clothing hairs having equal or unequal arms with wide lumina, and showing transitions to crop-hairs, are found in *Eugenia correaefolia*, Hook. et Arn. These hairs are specially remarkable in that the membrane which causes the duplication in the cases above mentioned can still be demonstrated in them with certainty, but since it is apposed to the longitudinal walls of the body of the hair along its whole length, it fails to produce duplication. Another new form of trichome is that of the shaggy hairs which have a clothing function, and are the cause of the hairy covering on the branches and the ciliation of the margins of the leaves in *Lhotskya genethylloides*, F. v. M. They are multiseriate structures, only one cell in breadth at the apex, and are characterized by the fact that the ends of the component cells stand off from the body of the hair in a papillose manner.

According to Porsch, the **secretory cavities** found in the species of *Eucalyptus* have an excretory mechanism similar to that found in the Rutaceae; it is composed of two parts, viz. (*a*) a passive portion, which in this case comprises the lid of the gland (with 2–4 lid-cells) as well as those cells of the wall which are situated immediately below the lid, and (*b*) an active portion constituted by the wall of the gland. Another noteworthy point is that in this case both the inner and outer walls of one or both lid-cells become split open, the outer walls tearing at certain points, pre-determined by their histological structure; the emission of secretion takes place through the slits thus formed, and not, as in the case of the Rutaceae, through 'preformed clefts between the walls.' Secretory cavities are present also in the genus *Aphanomyrtus*, which was formerly regarded as a doubtful member of the Myrtaceae (Koorders and Valeton).

The cork commonly contains unsuberized cells (phelloid-cells). In certain species of *Eucalyptus* (e.g. *E. globulus*, Labill.) the secondary bast includes numerous slightly sclerosed spicular cells, of an irregularly lobed, parenchymatous shape.

B. Lecythidaceae (pp. 355–357).

The following additional details regrading the clothing **hairs** are based on incidental investigations of my own. The hairy covering on the stems of *Lecythopsis rufescens*, Berg is constituted by 1–3-celled clothing hairs which vary in length and are provided with transverse walls of varying thickness. In some cases these hairs are united to form tufts (the ray-cells then occasionally consisting of two cells). The bicellular hairs further show a tendency to branch, since the longitudinal wall of the lower cell is sometimes drawn out on one side into a short pointed papilla. The clothing hairs on the floral buds of *Bertholettia excelsa*, Humb. et Bonpl. are for the most part unicellular, more rarely bicellular, with a thin transverse wall, and are peculiar in the fact that their longitudinal walls exhibit transverse folds at certain points; these folds penetrate into the lumen of the cell to a varying extent, and are placed at right angles to the longitudinal axis of the body of the hair.

According to Areschoug, **secretory cells** are found in the mesophyll in *Napoleonea Heudelotii*, Juss.

Literature: Höhnel, Gerberinden, Berlin, 1880, pp. 132 and 134 et seq.—Lamounette, Liber interne, Ann. sc. nat., sér. 7, t. xi, 1890, pp. 260–1.—J. E. Weiss, Korkbild., Denkschr. bot. Gesellsch. Regensburg, vi, 1890, p. 16 et seq.—Johannson, Wenig bek. Rinden, Diss., Dorpat, 1891, pp. 11 and 42 et seq.—[Korpow, *Melaleuca Cajeputi*, Diss., Moscow, 1894.]—Wartenberg, *Psidium Araça*, Diss., Erlangen, 1895, pp. 17–34.—Matteucci, Placche sugherose, Nuovo Giorn. bot. Ital.,

1897, p. 234.—[A. Schneider, Leaves of *Eucalyptus globulus*, Journ. of Pharmacol., New York, 1897, n. 7; abstr. in Just, 1897, ii, p. 107.]—Koorders and Valeton, *Aphanomyrtus*, Ann. Jardin Buitenzorg, Suppl. iii, 1898, p. 145.—Lenz, Folia Djambu, Ber. deutsch. pharm. Gesellsch., 1899, pp. 125–36, Tab.—Baranetzky, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xii, 1900, pp. 299–300.—[Palmieri, Anat. comp. del genere *Eucalyptus*, Napoli, 1900, 19 pp.].—Ursprung, Anat. u. Jahresringbild., etc., Diss., Basel, 1900, pp. 18–20 (*Psidium pomiferum*, L.).—[Baker and Smith, Eucalypts, Technic. Educat., Ser. 13, Techn. Mus., New South Wales, Sydney, 1902.]—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 356 et seq. (*Eugenia*, *Tristania*).—Fabricius, Laubbl.-Anat., Beih. z. bot. Centralbl., xii, 1902, p. 330 (*Barringtonia*).—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 20.—Porsch, Entleerungsapp. innerer Drüsen, Öst. bot. Zeitschr., 1903, pp. 256 and 318 et seq., Tab. ix.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 195–205 and 241–5.—Van Tieghem, Gaslondie et Psiloxyle, Ann. sc. nat., sér. 8, t. xix, 1904, pp. 349–60.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 46, 47, Tab. v. (*Napoleonaea*), pp. 110–11 and Tab. xvi (*Psidium*), pp. 130, 131 (*Eugenia*).—[Bourdillon, Timber of *Barringtonia*, Indian Forester, xxxi, 1905, pp. 89, 90.]—Günther, Anat. d. Myrtifloren, Diss., Breslau, 1905, pp. 24, 25, and 28–32.—Porsch, Spaltöffnungsapparat, Jena, 1905, p. 44.—[H. G. Smith, Calcium oxalate in the barks of the Eucalypts, Abstracts Roy. Soc. N. S. Wales, May, 1905, pp. 3, 4.]—[Pampanini e Pampaloni, *Xanthostemon*, Nuovo Giorn. bot. Ital., n. s., xiii, 1906, pp. 121–37.]—Piccioli, Legnami, Bull. Siena, 1906, pp. 151, 152.—Holtermann, Einfluss des Klimas, etc., 1907, p. 120 et seq. (*Eugenia*).—[For additional literature, see p. 1171.]

MELASTOMACEAE (pp. 358–368).

1. Review of the Anatomical Features. The occurrence of a characteristic stomatal apparatus, in which the pairs of guard-cells are almost completely surrounded by a single epidermal cell, is worthy of special note. A very striking feature of the hairy covering is the great scarcity of unicellular clothing hairs; uniseriate hairs are also of infrequent occurrence. Shaggy hairs showing manifold types of structure, as well as stellate, tufted, candelabra, and peltate hairs are far commoner. The hollow shaggy hairs of *Heterotrichum strigosum*, Tr., and the combinations of clothing and glandular hairs, found more especially in many of the Miconieae, also require special mention. External glands are widely distributed; they are clavate or their head is spherical, discoid, or otherwise shaped or (rarely) differentiated as a vesicular integumental gland; in other cases the glands are represented by glandular shaggy hairs. Peculiar 'retort-shaped glands' are found in *Bellucia*, papillose or hair-like appendages on the cells of the stalks of external glands in species of *Miconia*, &c., composite glandular hairs with two or more heads on a common stalk in species of *Calycogonium*, *Charianthus*, *Henriettella*, *Miconia*. Of internal secretory organs, tannin-idioblasts have recently been observed in species of *Clidemia* and *Miconia*. The only additional record of gelatinization of the epidermis of the leaf is afforded by *Pternandra*. Typical solitary crystals of the ordinary form appear to be wanting in the Melastomaceae, at least in the leaf; but in some cases the clustered crystals exhibit a reduction to short thick solitary crystals. To the enumeration of special features, which are of value in detailed diagnosis, we may add: the reticulate thickening of cells of the palisade tissue (species of *Graffenrieda* and *Meriania*); the sclerosis of cells of the mesophyll; the presence in certain members of the Order of spongy tissue, provided with peculiar collenchymatous thickenings; the occurrence of spiral tracheids in the mesophyll (species of *Bellucia*, *Henriettea*, and *Sonerila*).

2. Structure of the Leaf. The structure of the leaf has recently been investigated by Palézieux in numerous genera belonging to the Tribes Osbeckieae, Rhexieae, Merianieae, Oxysporeae, Sonerileae, Bertolonieae, Dissochaeteae, and Blakeae, as well as in the Astronieae and Memecyleae[1], and by

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[1] The following genera were examined: *Osbeckia*, *Rhadozepala*, *Otanthera*, *Melastoma*, *Tristemma*, *Dissotis*, *Dichaetanthera*, *Dinophora* (Tribe Osbeckieae); *Rhexia*, *Pachyloma*, *Monochaetum* (Tribe Rhexieae); *Huberia*, *Behuria*, *Opisthocentra*, *Adelobotrys*, *Meriania*, *Graffenrieda*

Gottschall in numerous genera of the Miconieae.[1] These new investigations help to confirm and extend the statements made in the earlier portion of this work.

According to Palézieux and Gottschall, the **stomata** vary very much in size. As regards the neighbouring cells both authors in the first place state that the pairs of guard-cells are frequently surrounded by three or more ordinary epidermal cells; side by side with stomata of this type, others with subsidiary cells placed transversely to the pore occasionally occur in one and the same species. The type of stoma just mentioned is found in most of the species of the Tribes Oxysporeae, Sonerileae, and Bertolonieae, as well as in *Medinilla* and many of the Miconieae. In stomata of this kind one of the two transversely placed cells often surrounds the greater part of the guard-cells, so that the other neighbouring cell merely touches them: in some cases the latter undergoes division by a wall approximately coincident with the direction of the pore, so that three neighbouring cells are found, one of which surrounds the pair of guard-cells in the way previously described. Stomata with neighbouring cells placed parallel or obliquely to the pore are rare (Miconieae). In certain species of *Osbeckia* and *Dissotis* the stomata are arranged parallel to the midrib. In *Clidemia heteroneura*, Cogn. the pairs of guard-cells occur singly in crateriform depressions in the surface of the leaf, while in species of *Clidemia* and *Miconia* they are surrounded by a cuticular ridge. Crowding of the stomata in groups is met with on the inner and (rarely) outer side of the domatia (inhabited by ants) found in species of *Tococa* and *Myrmidone*, as well as on the lower side of the leaves in *Leandra acutiflora*, Cogn., *Calycogonium Krugii*, Cogn., and *Ossaea Krugiana*, Cogn.; in the two species last named this phenomenon is due to the partial sclerosis of the lower epidermis.

Palézieux and Gottschall also mention the occurrence of **epidermal cells** with wide lumina and the gelatinous appearance of the cellulose-membranes of the epidermis as features characteristic of certain species; other characters are the cuticularization of the outer wall, the penetration of the cuticle into the lateral walls in the form of ridges or pegs, and the varied types of striation presented by the cuticle. The epidermal cells, found in the neighbourhood of the hairs and those situated above the crystal-idioblasts of the mesophyll, occasionally have a special shape. The case of *Huberia laurina*, DC. may be particularly noted in this connexion; here rows of elongated epidermal cells extend from gland to gland on the upper side of the leaf, these rows in their entirety forming a network. The only additional record of gelatinization of the epidermis of the leaf is furnished by *Pternandra*, so that mucilaginous epidermal cells are only of very rare occurrence in this Order. Upper epidermal cells showing palisade-like elongation are found also in species of *Calycogonium*, *Clidemia*, *Leandra*, *Miconia*, *Ossaea*, and *Tetrazygia*; such cells either form the whole of the epidermis or only occur in certain parts, which are situated above the idioblasts (containing clustered crystals) in the palisade-tissue and above the veins; the cells in this case are occasionally divided transversely or the lateral walls exhibit a concertina-like folding. Palisade-like elongation of the lower epidermal cells has been demonstrated only in certain species of *Miconia*. Papillose differentiation of the upper and lower epidermis and

(Tribe Merianieae); *Allomorphia*, *Oxyspora*, *Barthea*, *Blastus*, *Ochthocharis*, *Veprecella* (Tribe Oxysporeae); *Sonerila*, *Sarcopyramis* (Tribe Sonerileae); *Bertolonia*, *Salpinga*, *Triolena* (Tribe Bertolonieae); *Marumia*, *Dissochaeta*, *Amplectrum*, *Omphalopus*, *Medinilla* (Tribe Dissochaeteae); *Blakea* (Tribe Blakeae); *Astronia*, *Pternandra*, *Kibessia* (Tribe Astronieae); *Mouriria*, *Memecylon* (Tribe Memecyleae).

[1] The following genera: *Leandra*, *Conostegia*, *Charianthus*, *Tetrazygia*, *Miconia*, *Calycogonium*, *Heterotrichum*, *Tococa*, *Majeta*, *Myrmidone*, *Mecranium*, *Clidemia*, *Bellucia*, *Loreya*, *Henriettea*, *Henriettella*, *Ossaea*, *Myriaspora*.

the occurrence of a hypoderm composed of one or more layers have been observed in many species.

The upper epidermis is papillose in the following species: *Allomorphia umbellulata*, Hook. f., *Bertolonia marmorata*, Naud., *Clidemia cymifera*, Donn.-Smith, *Conostegia subcrustata*, Tr., *C. viridis*, Cogn. and *C. xalapensis*, Don, *Heterotrichum Eggersii*, Cogn. and *H. pallens*, DC., *Leandra solenifera*, Cogn., *Medinilla astronioides*, Tr., *Opisthocentra clidemioides*, Hook. f., *Sonerila obliqua*, Korth. and *S. secunda*, R. Br.; a papillose lower epidermis occurs in: *Bellucia brasiliensis*, Naud., *B. dichotoma*, Cogn., *B. grossularioides*, Tr. and *B. imperialis*, Sald. et Cogn., *Dichaetanthera altissima*, Cogn., *Dissochaeta pallida*, Bl., *Henriettea granulata*, Berg, *H. Martii*, Naud., *H. multiflora*, Naud., *H. Spruceana*, Berg and *H. succosa*, DC., *Kibessia hirtella*, Cogn., *Mecranium haemanthum*, Tr., *Miconia guianensis*, Cogn., *M. macrophylla*, Tr. and *M. Regelii*, Cogn., *Pternandra paniculata*, Benth. (subpapillose), *Tetrazygia bicolor*, Cogn. and *T. pallens*, Cogn. The papillae vary in shape, but are mainly conical or finger-shaped.

Hypoderm has been observed on the upper side of the leaf in: *Anplectrum assamicum*, Clarke, *Astronia Candolleana*, Cogn., *Blakea pulverulenta*, Vahl and *B. trinervia*, L. (both species with a two-layered epidermis), *Calycogonium squamulosum*, Cogn., *Charianthus coccineus*, Don, *C. corymbosus*, Cogn., *C. longifolius*, Cogn. and *C. nodosus*, Tr., *Clidemia blepharodes*, DC. (cells remarkably large and showing concertina-like folding), *Conostegia Donnell-Smithii*, Cogn., *C. procera*, Don, *C. subhirsuta*, DC. and *C. xalapensis*, Don, *Dichaetanthera altissima*, Cogn., *D. latifolia*, Cogn. and *D. rosea*, Cogn., *Dissotis incana*, Tr. (lateral walls exhibiting concertina-like folding), *Graffenrieda boliviensis*, Cogn. and *G. emarginata*, Tr., *Henriettea angustifolia*, Berg, H. *granulata*, Berg, *H. Martii*, Naud., *H. multiflora*, Naud., *H. Spruceana*, Berg and *H. succosa*, DC., *Henriettella fascicularis*, Tr., *H. Macfadyenii*, Tr. and *H. membranifolia*, Cogn., *Loreya nigricans*, Tr., *Marumia pachygyna*, Korth., *Mecranium amygdalinum*, Tr. and *M. haemanthum*, Tr., *Medinilla astronioides*, Tr., *M. magnifica*, Lindl., *M. myrtiformis*, Tr., *M. papillosa*, Bak., *M. parvifolia*, Bak., *M. pauciflora*, Hook. f. and *M. rubicunda*, Bl., *Melastoma imbricatum*, Wall., *M. Malabathricum*, L., *M. normale*, L. and *M. obvolutum*, Jack, *Meriania boliviensis*, Cogn. and *M. calophylla*, Tr., *Miconia affinis*, DC., *M. cubensis*, Sauv., *M. difficilis*, Tr., *M. foveolata*, Cogn., *M. glandulifera*, Cogn., *M. hirtella*, Cogn., *M. lilacina*, Tr., *M. quadrangularis*, Naud., *M. Sintenisii*, Cogn. (in the species last named the cells of the one-layered hypoderm have very wide and deep lumina, are sometimes transversely divided, and are further provided with exceptionally thick and gelatinous inner walls which have a milky white colour and extend upwards in the form of a wedge between the lateral walls) and *M. theaezans*, Cogn., *Mouriria domingensis*, Spach., *M. grandiflora*, DC., *M. guianensis*, Aubl. and *M. myrtilloides*, Poir., *Ochthocharis borneensis*, Bl., *Pachyloma coriaceum*, DC. and *P. huberioides*, Tr., *Sonerila grandiflora*, R. Br. and *S. moluccana*, Roxb., *Tetrazygia angustifolia*, DC., *T. bicolor*, Cogn., *T. crotonifolia*, DC., *T. discolor*, DC., *T. elaeagnoides*, DC., *T. hispida*, Macf. and *T. pallens*, Cogn. According to Holtermann, *Kendrickia Walkeri* also has a hypoderm, which occupies half the thickness of the leaf.

In *Miconia tetrandra*, Naud. the upper epidermis in transverse section consists of a varying number of layers, the cells of which are of unequal size; in this species cells of varying size are cut off irregularly from the outer side of the larger epidermal cells.

The following structural features of the **mesophyll** require special mention. The species of *Bellucia* have a palisade-tissue, composed of two or three layers of cells, which are fitted in among one another in such a way that they are firmly joined together. Reticulate thickening of isolated palisade-cells, similar to that occurring in *Clusia rosea*, L. (Guttiferae), is found in *Meriania paniculata*, Tr. var. *parvifolia*, Cogn., and *Graffenrieda emarginata*, Tr. In *Medinilla papillosa*, Bak. isolated cells of the palisade-tissue are sclerosed. Special tannin-idioblasts, which are filled with brown contents in herbarium-material, have been observed in the palisade-tissue in *Clidemia Kappleri*, Cogn., and *Miconia compressa*, Naud., whilst in other members of the Order all the palisade-cells have brown contents, and at the same time show folded

lateral walls; large lenticular starch-grains occur in the mesophyll in species of *Meconium* and *Miconia*. Collenchymatous thickening of the spongy tissue, similar to that found in *Pachyloma coriaceum* (see p. 360) is recorded by Palézieux also in species of *Anplectrum*, *Graffenrieda*, *Medinilla*, *Melastoma*, *Meriania* and *Ochthocharis*. Spiral tracheids have been observed at the limit of palisade and spongy tissues in *Sonerila moluccana*, Roxb., and in the spongy tissue in *Bellucia imperialis*, Cogn. et Sald. and *Henriettea angustifolia*, Berg. In *Medinilla papillosa*, Bak. and *M. parvifolia*, Bak. the middle layer of the spongy tissue is sclerosed, while in species of *Leandra*, *Miconia*, and *Ossaea* the walls of all the cells of the spongy tissue are remarkably thickened; in *Huberia semiserrata*, DC. the spongy tissue only contains isolated sclerosed cells. Gottschall lastly mentions the occurrence of strongly sclerosed and pitted cells, having an undulated outline, in the spongy tissue of *Henriettella glabra*, Cogn., and of strongly sclerosed cells of a serpentine form in that of *Miconia tetrandra*, Naud.

A consideration of the data recently published seems to show that sclerenchyma is more frequently found accompanying the **veins** than was formerly supposed, although the accompanying tissue for the most part exhibits collenchymatous differentiation. Gottschall states that the veins are vertically transcurrent in species of *Charianthus*, *Clidemia*, *Henriettea*, *Leandra*, *Miconia*, *Tetrazygia*, and *Tococa*; according to the same author, the more delicate veins are frequently provided with a distinct parenchyma-sheath, which is occasionally sclerosed. Gottschall and Palézieux also mention the occurrence of more or less elongated rod-cells in the parenchymatous ground tissue of the veins in species of numerous genera [1], while Gottschall records spindle-shaped sclerenchymatous cells in the same position in *Miconia rhytidophylla*, Naud.

In the Tribes recently investigated **oxalate of lime** is also for the most part deposited in the form of clustered crystals, which vary in size and shape. They are found in the mesophyll, the veins, the hypoderm (e.g. in species of *Blakea*, *Dichaetanthera* and *Melastoma*), and more rarely also in the epidermis (embedded in the strongly-thickened inner wall in *Miconia campestris*, Tr., according to Gottschall [2]; and in the epidermis of the veins in species of *Dichaetanthera*, according to Palézieux). The large cells of the palisade-tissue, which are occupied by clustered crystals, commonly penetrate between the epidermal cells after the manner of a wedge, and occasionally give rise to transparent dots in the leaf. A peculiar arrangement of the clustered crystals has been observed in the leaf in species of *Blakea*; the crystals are contained in three horizontal layers (viz. (*a*) in the hypoderm or in the layer of palisade situated beneath the upper epidermis, (*b*) in the layer of cells adjoining the palisade-tissue, and (*c*) in the cell-layer lying above the lower epidermis). Sphaerites are found in the bases of the shaggy hairs ('Zottenfüsse') also in the Osbeckieae and Rhexieae. Other noteworthy features are as follows: the occasional reduction of the clustered crystals to a short and thick solitary crystal (especially in *Miconia atrata*, Wawra and *Ossaea micrantha*, Macf.); the presence of small monoclinic crystals in the cells containing clustered crystals in *Miconia buddleioides*, Tr. and *M. trichotoma*, DC., and the styloids, recorded by Gottschall, in *Calycogonium squamulosum*, Cogn.

The **hairy covering** is again very manifold in the Tribes investigated by Palézieux and Gottschall. The clothing hairs are represented by the same

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[1] These genera are: *Anplectrum*, *Behuria*, *Clidemia*, *Conostegia*, *Dichaetanthera*, *Dissochaeta*, *Henriettella*, *Huberia*, *Leandra*, *Loreya*, *Marumia*, *Miconia*, *Omphalopus*, *Pachyloma*, *Tetrazygia*, *Tococa*, *Veprecella*.

[2] Gottschall mentions the occurrence of cells containing clustered crystals and causing large hemispherical protuberances on the upper side of the leaf in *Heterotrichum Eggersii*, Cogn. and *H. patens*, Cogn., but he does not state whether they belong to the epidermis.

types as those previously enumerated on the ground of the older investigations (see p. 361). Unicellular or uniseriate trichomes are also rare in the Tribes recently investigated (and consequently in the Melastomaceae generally). Palézieux records unicellular and uniseriate clothing hairs in *Kibessia echinata*, Cogn. and uniseriate trichomes, the cells of which are in part ventricose and often striulate, in species of *Sonerila* and *Veprecella*, while Gottschall describes unicellular hairs in *Miconia plumifera*, Tr. var. *Bangii*, Cogn. The following modifications of the uniseriate hairs are found :—trichomes, the ends of which develop a few ray-cells, among which a club-shaped multicellular gland is occasionally (*Veprecella microphylla*, Cogn.) included (species of *Veprecella*); and trichomes consisting of a row of rounded cells, the terminal cell being glandular (*Sonerila obliqua*, Korth. and *S. secunda*, R. Br.). The shaggy hairs, like those formerly observed, are either parenchymatous or prosenchymatous; their mode of insertion, as well as their shape and length, varies; in some cases they are bent in the form of a hook and they may have the shape of a short awn or wart, &c. In the larger types of shaggy hairs there is a vascular bundle in the lower portion (species of *Majeta*, *Myrmidone* and *Tococa*). Palézieux records shaggy hairs with a papillose epidermis in species of *Dichaetanthera*, *Dissotis*, *Osbeckia*, *Rhodosepala* and *Tristemma*, brush-like shaggy hairs in species of *Dichaetanthera*, *Dissotis*, *Melastoma*, *Monochaetum* and *Otanthera*, shaggy hairs of the abietiform or candelabra-type in species of *Dichaetanthera*, *Dissochaeta*, *Dissotis*, *Kibessia*, *Marumia*, *Meriania* and *Omphalopus*, and shaggy hairs resembling the leaf of a moss in species of *Dichaetanthera* and *Melastoma*. Gottschall describes the following types :—smooth shaggy hairs composed of two or three rows of prosenchymatous cells, which are subdivided by two or three thin transverse walls, such hairs commonly bearing a glandular head at their apex (species of *Clidemia* and *Tococa*); prosenchymatous shaggy hairs with a papillose epidermis (species of *Clidemia*, *Conostegia*, *Henriettea*, *Leandra*, *Miconia* and *Ossaea*); prosenchymatous shaggy hairs terminating in a stellate trichome (species of *Conostegia* and *Leandra*); prosenchymatous shaggy hairs of candelabra- or antler-like form (species of *Clidemia*, *Leandra* and *Ossaea*); parenchymatous brush-like shaggy hairs (species of *Miconia* and *Tococa*); parenchymatous shaggy hairs with more or less pronounced dendroid branching (species of *Conostegia*, *Leandra* and *Miconia*). The different forms of hairs just referred to are moreover occasionally (species of *Clidemia*, *Leandra*, *Miconia*, *Ossaea*) seated on conical prominences of varying height on the surface of the leaf, while small shallow pits correspond to these prominences on the lower side of the leaf. The hollow, bristle-like shaggy hairs of *Heterotrichum strigosum*, Tr. still require special mention; they are placed with their tips pointing towards the apex of the leaf and are adpressed to its surface; the epidermis of these hairs is formed by elongated prosenchymatous cells, beneath which a layer of short palisade-cells is situated, while the interior of the hair is occupied by a large intercellular space. Regarding the stellate, tufted, candelabra and peltate hairs observed by Palézieux and Gottschall we may mention the following details. Palézieux records stellate or tufted hairs with a short, mostly biseriate stalk and a varying number of ray-cells in species of *Anplectrum*, *Astronia* (probably on Cogniaux's authority and not on the basis of personal observation), *Dissochaeta*, *Marumia* (trichomes occasionally of the candelabra-type) and *Omphalopus* (trichomes likewise occasionally resembling candelabra-hairs), while peltate hairs occur not only in the plant investigated by Bachmann, which belongs to *Astronia Candolleana*, Cogn. (not *A. papetaria*), but also according to Cogniaux in many species of *Astronia*. The types of hairs last discussed show much greater diversity of form among the Miconieae, where they are often connected by transitional

forms, which occur even in the same species or on one and the same leaf. Gottschall in the first place mentions stellate hairs with a short, mostly biseriate stalk and a few ray-cells, which occasionally include a gland, in species of *Calycogonium, Clidemia, Conostegia, Heterotrichum, Leandra, Majeta, Miconia, Myrmidone, Ossaea* (described as tufted hairs in the special part of Gottschall's paper), *Tetrazygia*, and *Tococa*. The following are special forms of the stellate hairs :—stellate hairs, in which the ray-cells are swollen in a bulbous manner at their base (species of *Clidemia, Miconia campestris*, Tr.) ; stellate hairs with a very long parenchymatous or prosenchymatous stalk (species of *Calycogonium, Clidemia, Miconia*) ; stellate hairs in which the basal cells of the comparatively short stalk are divided into compartments by numerous transverse walls (species of *Miconia*) ; stellate hairs, the ray-cells of which have narrow lumina and a serpentine outline (species of *Clidemia* and *Miconia*) ; lastly, the pulvinate stellate hairs of *Miconia rugosa*, Tr. and *M. tomentosa*, Don, in which the basal portions of the cells, which radiate out in all directions, are fused to form a hemispherical cushion. Trichomes described by Gottschall as tufted hairs, but not very sharply distinguished from the stellate hairs (apparently only by the larger number of ray-cells), are found among the Miconieae in species of *Calycogonium, Charianthus, Clidemia, Conostegia, Miconia* and *Tetrazygia*. Candelabra-hairs with ray-cells, which are horizontal or occasionally even point upwards, are present in species of *Clidemia, Conostegia, Miconia* and *Tetrazygia*. According to Gottschall, distinct peltate hairs occur in *Miconia fulva*, DC., *M. lepidota*, DC. and *M. tiliaefolia*, Naud. (in the first two species with long stalks ; in the third species with stalks of varying length), and in *Tetrazygia bicolor*, Cogn. (in small pits in the surface of the leaf). They are derived from tufted hairs, in which the upper ray-cells have undergone reduction ; these abbreviated ray-cells are seated on the top of the shield, and in some cases form a more or less distinct small ' upper scale,' which in *M. fulva* even includes an external gland ; in the same way the uppermost tier of cells in the stalk occasionally (*M. lepidota*) grows out to form a small ' lower scale.' Tufted hairs resembling small scales occur also in other species of *Miconia*, as well as in *Calycogonium squamulosum*, Cogn. and *Henriettella Macfadyenii*, Tr. It remains to mention that all the diverse forms of clothing hairs found in the Miconieae (with the exception of the hollow shaggy hairs of *Heterotrichum* and the bristle-hairs of *Calycogonium Krugii*, Cogn., and a few species of *Ossaea*) occur also in combination with glands ; in the Tribes investigated by Palézieux such combined forms of clothing and glandular hairs have been demonstrated only in *Veprecella* (see above). We shall return to these intermediate forms once more below.

The following details may be mentioned regarding the **external glands.** The species belonging to the Tribes examined by Palézieux for the most part have small, multicellular external glands, which are either clavate or exhibit a distinctly demarcated stalk and a multicellular head. Uniseriate glandular hairs in which the cells of the stalk are ventricose and frequently striulate, are found in *Sonerila* ; glands with a long stalk and a bicellular head, divided by a vertical wall, occur in species of *Allomorphia, Medinilla* and *Oxyspora* ; glandular hairs with a disc-shaped head divided by vertical walls in *Barthea chinensis*, Hook. f. (glandular disc composed of four cells), species of *Huberia* (glandular disc composed of a larger number of cells, occasionally with a lobed margin) and species of *Graffenrieda* (glandular disc placed excentrically on the stalk) ; vesicular integumental glands, similar to those found in the Labiatae, in *Blastus cochinchinensis*, Lour. Palézieux mentions the occurrence of glandular shaggy hairs only in species of *Rhexia* and *Sonerila*. According to Gottschall, the external glands found in the Miconieae exhibit a much greater diversity of shape. Uni- or biseriate, filiform external glands have been observed in species of

Henriettea, Miconia and *Tetrazygia*. Quite a special form of hair is constituted by the uniseriate retort-shaped glands (hydathodes ?) of the species of *Bellucia*; the ventricose portion of these glands is inserted among the epidermal cells and is divided by a large number of thin transverse walls into low and broad cells, which pass over into cylindrical cells in the region of the neck, while the apex of the trichome is occupied by a slightly spherical terminal cell; the cells of the neck and of the ventricose portion have thick walls except for the transverse walls in the latter and for small rounded areas which remain unthickened in the middle of the transverse walls of the lower cells of the neck; the uppermost cells of the neck and the terminal cell have thin walls. Bent uniseriate glandular hairs with a cylindrical head and bearing a few backwardly directed papillae at the point of bending are found in species of *Henriettella, Loreya*, and *Myriaspora*; biseriate, club-shaped glandular hairs occur in species of *Calycogonium, Clidemia, Heterotrichum, Majeta, Miconia, Myrmidone* and *Tococa*. Here we may also include glandular hairs, the head of which is bent in relation to the biseriate stalk in a more or less geniculate manner, while the stalk often bears one or more ray-cells. The head in these hairs exhibits the following types of structure; it is:—small, oval or spherical, either unicellular or bicellular owing to the presence of a division-wall in the plane of bending of the stalk, in species of *Leandra, Meconium* (?, cf. Gottschall, p. 137), *Miconia, Ossaea* and *Tetrazygia*; ellipsoidal, clavate or cylindrical, and multicellular in species of *Calycogonium, Clidemia, Conostegia, Heterotrichum, Leandra* and *Tetrazygia*; ligulate and bi- to multicellular in species of *Clidemia, Leandra, Miconia* and *Ossaea*; disc-shaped and multicellular in species of *Conostegia*; reniform to spathulate and multicellular in species of *Miconia* (in certain species, especially *M. quadrangularis*, Naud., the stalk bears hairy appendages exhibiting dendroid branching); lastly, cordate and multicellular in species of *Leandra*. Other noteworthy forms are constituted by external glands with a multicellular head resembling a blackberry in shape (species of *Miconia* and *Tetrazygia*) and glands in which four or more multicellular heads are borne on a common stalk (*Calycogonium squamulosum*, Cogn. with four heads, which are fused to form a rosette; *Henriettella Macfadyenii*, Tr. with 2–5 heads, which are disc-shaped and include gelatinized cells in the glands situated above the veins; species of *Charianthus* with a varied number of heads corresponding to the number of rows of cells in the stalk; *Miconia annulata*, Tr. with several reniform or spathulate heads). It remains to mention that the two basal cells of the stalk in the glandular hairs of certain species of *Miconia* are transversely septate by means of a large number of walls. To return to the combined clothing and glandular hairs found in the Miconieae we may in the first place point out that the external glands are very commonly combined with stellate, tufted, candelabra, and peltate hairs. Smooth glandular shaggy hairs with a terminal external gland occur in species of *Clidemia, Henriettea, Heterotrichum, Majeta, Miconia, Myrmidone, Ossaea* and *Tococa*; the gland is either uniseriate and filiform, or biseriate and club-shaped, or large and spherical to ellipsoidal and provided with a palisade epidermis. In species of *Majeta, Myrmidone* and *Tococa* the stalk of these glands contains a vascular bundle, while in *Heterotrichum Eggersii*, Cogn. and *Miconia rhytidophylla*, Naud. it includes pitted fibrous cells. Finally, shaggy hairs of the candelabra type provided with a terminal gland are found in species of *Henriettea* and *Henriettella*.

For the structure of the ant-domatia of *Majeta, Myrmidone* and *Tococa*, see Gottschall, loc. cit., pp. 27, 28.

3. Structure of the Axis. Formation of phelloid-cork takes place also in the Melastomaceae (F. E. Weiss and Günther, ll. cc.). According to Van

Tieghem, interxylary phloem is found also in the wood of the root in *Memecylon ramiflorum*.

Literature: Went, Haft- u. Nährwurzeln, Ann. Jardin Buitenzorg, xii, 1895, p. 57.—Jönsson. Anat. Bau d. Bl., Acta Univ. Lund., xxxii. 2, 1896.—Palézieux, Anat.-syst. Untersuch. d. Bl. der Melastom. mit Ausschluss der Triben der Microlicieen, Tibouchineen und Miconieen, Bull. Herbier Boissier, vii, 1899, App. v; Diss., Munich, 85 pp., 3 Tab.—Gottschall, Anat.-syst. Untersuch. d. Bl. d. Melastom. aus der Tribus der Miconieae, Mém. Herbier Boissier, 1900, n. 19; Diss., Munich, 175 pp., 3 Tab.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 68.—Fabricius, Laubblatt-Anat., Beih. z. bot. Centralbl., xii, 1902, pp. 328-29.—Günther, Anat. d. Myrtifloren, Diss.. Breslau, 1905. pp. 26-27.—Holtermann, Einfluss des Klimas etc., 1907, pp. 134-135 (*Kendrickia, Medinilla*).—
[For further literature, see p. 1171.]

LYTHRARIEAE (pp. 369-373).

1. The Review of the Anatomical Features requires the following additions. The cork is for the most part differentiated as phelloid-cork. There is no uniform and characteristic type of stoma in the Lythrarieae. Gelatinized cells are occasionally found also in the tissue accompanying the veins. Oxalate of lime is excreted also in the form of sphaerites or of small acicular or otherwise shaped crystalline bodies. As regards the hairy covering we may point out that small external glands do not occur in this Order, that short, uni- or bicellular papillose hairs are common, and that slightly branched multicellular clothing hairs are present in *Decodon*; the tufted hairs found in *Lagerstroemia* are accompanied by trichomes exhibiting sympodial branching or resembling a fir-tree. To the previous enumeration of special features given at the end of the general review the following may be added:—the occurrence of division-walls in the epidermis of the leaf; presence of hypoderm in the leaf (also in species of *Ginoria* and *Lagerstroemia*); formation of papillae on the epidermis of the leaf (also in species of *Diplusodon* and *Lagerstroemia*); crystal-idioblasts with clustered or solitary crystals in the mesophyll; groups of cells containing clustered crystals in the mesophyll (*Pemphis*); occurrence of ordinary solitary crystals (*Lagerstroemia lanceolata*, Wall.), and of sphaerocrystalline or tufted masses of an unknown substance (species of *Decodon*, *Diplusodon*, *Heimia*, *Lagerstroemia*, *Lythrum*) in the epidermis of the leaf.

2. Structure of the Leaf. Eberlein's recent investigations, on which the following description is based, deal with the genera *Lythrum*, *Woodfordia*, *Pleurophora*, *Galpinia*, *Pemphis*, *Diplusodon*, *Physocalymna*, *Lafoensia*, *Crenea*, *Nesaea*, *Heimia*, *Decodon*, *Grislea*, *Adenaria*, *Ginoria*, *Lagerstroemia*, and *Lawsonia*.

The statement made in the earlier portion of this work that there is no special type of stoma requires modification in the sense that **stomata** of a special type are not of general occurrence. In *Lythrum nummulariifolium*, Lois., however, the pairs of guard-cells are accompanied by three neighbouring cells, which are all of different sizes; in *Pleurophora* and *Heimia myrtifolia*, Cham. et Schlecht., they are surrounded by three ordinary neighbouring cells; in *Crenea* there are commonly four neighbouring cells, and so on; in *Lafoensia punicifolia*, DC. and *Lagerstroemia speciosa*, Pers., the neighbouring cells are narrow, while in *Sonneratia*, according to Areschoug, they appear arranged in a rosette. The stomata are either absent on the upper side of the leaf or are present in varying numbers; they either lie on a level with the epidermis or are slightly raised above it, or are depressed; occasionally pairs of guard-cells of two sizes are found on one and the same surface of the leaf; in some cases (species of *Diplusodon*, *Heimia*, *Lythrum*, *Nesaea*, *Pleurophora*) the stomata are placed with their pores directed approximately parallel to the principal vein. The degree of thickening presented by the outer wall of the

epidermis and the varied nature of the cuticle, which is occasionally granular or striated, furnish characters for specific diagnosis; a noteworthy feature lies in the occurrence of what is called 'an internal granulation' in species of *Diplusodon*. Eberlein demonstrated gelatinization of the epidermis of the leaf in certain species of all the genera investigated by him with the exception of *Grislea* and *Woodfordia*. In certain species of *Ginoria*, *Lagerstroemia* and *Pemphis* the upper epidermal cells undergo local divisions by means of horizontal walls. Hypoderm is developed on the upper side of the leaf also in *Ginoria Rohrii*, Köhne (one-layered) and *Lagerstroemia lanceolata*, Wall. (1–2-layered). Typical papillae are found on the lower surface of the leaf also in *Diplusodon epilobioides*, DC. (papillae here short and pectinate, and serving as centres for the cuticular striation), as well as in *Lagerstroemia hypoleuca*, Kurz, *L. lanceolata*, Wall. and *L. parviflora*, Roxb. The **mesophyll** varies from bifacial to centric in structure. Sclerenchyma may or may not be present in the **veins**. In species of *Decodon*, *Grislea*, *Lagerstroemia* and *Physocalymna*, even the smaller veins are vertically transcurrent. In the larger veins the lower group of soft bast in the bicollateral vascular system occasionally exhibits reduction, so that only that situated on the upper side (the inner bast) is strongly developed. Another striking feature observed in certain species is the occurrence of numerous mechanical elements or of spiral tracheae with wide lumina in the wood of the larger veins. Storage and terminal tracheids in the form of enlarged pitted cells are found in species of *Crenea*, *Diplusodon*, and *Lawsonia*. Gelatinized cells occur also in the tissues accompanying the veins in species of *Diplusodon*, *Lagerstroemia* (here also in the hypoderm) and *Nesaea*.

Oxalate of lime, as already previously stated, is generally deposited in the form of clustered crystals. The latter vary both in size and structure; they are either star-shaped or built up of small and delicate needles; in other cases again they are more of the nature of sphaerites or consist of granular conglomerates of individual crystals. In addition to these forms we have typical sphaerites (especially in *Pleurophora*, also in *Grislea* and *Woodfordia*), ordinary solitary crystals of the rhombohedral type, or presenting some other shape, and small crystalline bodies assuming the shape of rods, needles or granules; the latter are found both in the mesophyll and in the integumental tissue (in species of *Adenaria*, *Decodon*, *Diplusodon*, *Heimia*, *Lafoensia*, *Lawsonia*, *Lythrum*, *Nesaea*, *Physocalymna*, *Pleurophora*, *Woodfordia*). Other features requiring special mention are: the occurrence of small groups of cells filled with small clustered crystals in the mesophyll, which is specially characteristic of *Pemphis* (*P. acidula*, Forst.); the occurrence in the mesophyll of large idioblasts, containing clustered (species of *Diplusodon*, *Galpinia* and *Nesaea*) or large solitary crystals (*Lafoensia nummulariifolia*, St. Hil., and certain species of *Lagerstroemia*), these idioblasts in some cases giving rise to transparent dots in the leaf (in *Lagerstroemia*, Köhne's 'folia glanduloso-punctata'); lastly, the presence of relatively large solitary crystals in the epidermis in *Lagerstroemia lanceolata*, Wall., these crystals being enveloped by a cell-membrane in the same way as in Rosanoff's crystals. Before leaving the discussion of the modes of excretion of oxalate of lime, we may refer to the sphaerocrystalline, tufted or variously shaped masses of an unknown substance, which Eberlein observed in the integumental tissue in certain species of *Decodon*, *Diplusodon*, *Heimia*, *Lagerstroemia* and *Lythrum* (in *Lythrum* both in the dried and in the living leaf).

Among the types of clothing **hairs** found in the genera recently investigated, simple unicellular or uniseriate forms are again the most important. Short unicellular papillose hairs, which are occasionally divided into two cells by a transverse wall, are very common (species of *Adenaria*, *Decodon*,

Diplusodon, Grislea, Ginoria, Lagerstroemia, Lythrum, Nesaea, Pleurophora, Physocalymna, Woodfordia). The longer hairs occurring in this Order are either unicellular or uniseriate; the latter may have thin or thick division-walls, and their component cells are occasionally articulated with reference to one another. The surface of the clothing hairs is not uncommonly granular or verrucose. The appearance of relatively thin transverse and longitudinal walls in the lower portion of the body of the hair in *Lagerstroemia indica*, L., leads to the production of shaggy hairs. The species of *Lagerstroemia* belonging to the section *Trichopodium* have branched hairs. In *L. Engleriana*, Köhne, these hairs are of sympodial structure; their main stem is uniseriate and consists of a varying number of cells, which, with the exception of those at the base, are drawn out into rays emanating in various directions and more or less bent; in this way forked or antler-shaped hairs are produced. Among these trichomes we may include certain hairs found in other species of *Lagerstroemia*; the latter are either tufted or abietiform and consist of a uniseriate stalk and a varying number of tiers of cells, which are drawn out into rays. Little branched multicellular clothing hairs, which are either forked or antler-shaped, are found side by side with unbranched trichomes in *Decodon verticillatus*, Ell. In some cases (*Diplusodon, Physocalymna*) the surrounding cells are prolonged on to the clothing hairs after the manner of subsidiary cells. The leaves of the species of *Grislea* bear black glandular dots which had not previously been subjected to a close examination; according to Eberlein, they are due to shortly stalked external glands which have a one-layered wall and a large intercellular secretory space in their interior, and are thus quite similar to the glands found in the genera *Adenaria* and *Woodfordia*[1]. Small external glands are completely wanting in this Order. Areschoug mentions the occurrence of cork-warts on the leaves in *Sonneratia caseolaris*, Engl. and *S. lanceolata*, Miq.

3. Structure of the Axis. Günther has recently examined the structure of the axis, more especially with reference to the development of the cork, in the following genera: *Rotala, Ammannia, Peplis, Adenaria, Woodfordia, Cuphea, Lythrum, Pleurophora, Nesaea, Heimia, Decodon, Crenea, Ginoria, Pemphis, Diplusodon, Lafoensia, Physocalymna, Lawsonia* and *Lagerstroemia*. The vascular bundles are invariably bicollateral, and the perforations of the vessels are always simple. The groups of pericyclic fibres are occasionally united to form a ring (species of *Ammannia, Diplusodon, Lafoensia*). In *Lafoensia Vandelliana*, Cham. et Schlecht. the transverse section shows several mechanical rings composed of bast-fibres intermingled with stone-cells. In *Lagerstroemia* and *Diplusodon* the cells of the pith are strongly sclerosed, while in *Adenaria floribunda*, H. B. K. there are isolated stone-cells in the pith. According to Günther, the concentric arrangement of the crystal-cells (containing solitary or clustered crystals) in the bast, as seen in a transverse section of the branch, is a feature deserving special notice.

To the previous account (on p. 372) of the **cork** we may add the following details. The cork develops in 'deep layers' (probably in most cases in the pericycle), also in *Crenea, Cuphea, Diplusodon, Ginoria* and *Heimia*. The cells of the cork are for the most part tabular, but in some cases they are cubical; they are very small in species of *Ammannia, Crenea, Nesaea* and *Peplis*. Günther distinguishes the following four types of differentiation of the cork. *Crenea surinamensis*, Köhne and *Peplis Portula*, L. have a single layer of cork, which may be regarded as an endodermis, while on its outer side there is a massive primary aerenchyma. *Decodon verticillatus*, Ell. has

[1] The cause of the 'folia utraque pagina nigro-punctulata' found in *Pemphis madagascariensis*, Köhne still remains to be determined.

a normal many-layered periderm, on the outer side of which primary aerenchyma is again strongly developed. Typical cork consisting of a still larger number of layers is found in *Pemphis acidula*, Forst. and *Pleurophora pungens*, Don. In the remaining members of the Order, investigated by Günther, the cork contains phelloid-cells (see also J. E. Weiss, loc. cit.). The cells given off by the phellogen on its outer side undergo subsequent division by means of tangential walls so that each gives rise to three cells; of these only the middle one develops into a typical cork-cell, while the outer and inner cells retain their cellulose-walls (*Lythrum*) or become lignified (*Cuphea*, *Heimia*) or sclerosed (in the remaining genera). In the fourth type small intercellular spaces are generally present between the cells of the periderm.

Typical (secondary) aerenchyma is developed also in the floating stems of *Nesaea verticillata* (Schrenk).

4. Structure of the Root. The interxylary phloem in the wood of the root of *Lythrum Salicaria* is not given off by the cambium on its inner side, but arises by a process of secondary differentiation in the wood-parenchyma.—For the structure of the respiratory roots of *Sonneratia*, see also Westermaier, loc. cit. Among the results of his investigations we need only mention that there are no spicnlar cells in those parts of the roots which are embedded in the mud at the bottom of the water, their place being taken by special elongated cells having thick walls and acting like springs.

Literature: Hohnel, Gerberinden, Berlin, 1880, p. 137 et seq.—Costantin, Tiges d. pl. aquat., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 et seq. and pl. xiv.—[Schrenk, Float. tissue of *Nesaea*, Bull. Torrey Bot. Club, xvi, 1889, pp. 315–23 and pl. xcv–vii; abstr. in Bot. Centralbl., 1890, iii, p. 120.]—J. E. Weiss, Korkbild., Denkschr. bot. Gesellsch. Regensburg, vi, 1890, p. 6 et seq.—Leisering, Interxylares Leptom, Diss., Berlin, 1899, p. 30.—Kearny, in Contrib. U. S. Nat. Herb., v, n. 5, 1900, p. 303 (*Ammannia*).—Westermaier, Pneumatophoren, Freiburg i. d. Schw., 1900, 53 pp., 3 Tab.—Areschoug, Mangrovepfl., Bibl. bot., Heft 56, 1902, pp. 67–9 and Tab. xi–xiii (*Sonneratia*, *Pemphis*).—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 355 (*Sonneratia*).—Kohne, Lythraceae, in Pflanzenreich, Heft 17, 1903, pp. 4, 5.—Eberlein, Beitr. z. anat. Charakt. d. Lythrar., Diss., Erlangen, 1904, 78 pp.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 119, 120 and Tab. iii and xxii (*Lawsonia*), pp. 122–3 and Tab. iii, iv (*Lafoensia*).—Günther, Anat. d. Myrtifloren mit bes. Berücks. d. Lythrar., Diss., Breslau, 1905, 39 pp., esp. pp. 5–20.—Piccioli, Legnami, Bull. Siena, 1906, p. 147.—Holtermann, Einfluss des Klimas, etc., 1907, p. 92 (*Pemphis*).—[For further literature, see p. 1170].

ONAGRARIEAE (pp. 373–376).

In the summary of the **anatomical features** of the Onagrarieae given at the beginning (p. 373) of the former description the statement as to the absence of external glands must be cancelled. The simple perforations of the vessels are accompanied by a small number of scalariform perforations in certain members of the Order. The cork of *Trapa*, unlike that of the other Onagrarieae, develops beneath the epidermis.

An account of the structure of the leaf, stem, and root in this Order has been published also by Grosse, whose work was not taken into consideration in the previous description. The following details are taken from his paper as well as from the other new literature. The closure of the **stomata** in *Trapa*, as in other floating plants, takes place solely by means of the cuticular ridges on the guard-cells (Haberlandt). Raphides are found also in *Eucharidium*. It remains doubtful whether the small prismatic solitary **crystals**, observed by Netolitzky in the apex of the leaf of *Isnardia* (*Ludwigia*) *palustris*, L., are of constant occurrence. In glycerine-preparations of the leaves of *Oenothera biennis*, L., Netolitzky met with yellowish crystalline deposits of an unknown substance. Side by side with the raphide-sacs one occasionally (e.g. in *Epilobium hypericifolium*, Tausch) finds mucilage-sacs containing no raphides or occupied only by a small number of short needles. The unicellular

clothing **hairs** commonly have a granular or verrucose surface. The short club-shaped unicellular hairs of *Oenothera Romanzowii*, Ledeb. and *Clarkia pulchella*, Pursh, &c., as well as the rather longer unicellular trichomes of *Oenothera biennis*, L., in which the apex is slightly swollen, have thin walls, are filled with granular contents in the living plant and probably have a glandular function; short club-shaped trichomes are recorded by Netolitzky also in *Circaea*, while long ones are stated to occur in *Epilobium* (see also Theorin, loc. cit.). Structures resembling stipules are found at the base of the petiole in *Ludwigia palustris*, Ell., and in the species of *Jussiaea* (Meehan), but they still require careful investigation. In *Jussiaea* these structures are somewhat flattened and ovate and have a green colour; they do not contain any vascular bundles, although there are numerous raphide-sacs, and they dry up at an early stage. The 'secretory receptacles' described by Grosse as occurring in the axis of *Trapa* are probably in reality a local pathological formation of cork. According to Grosse, carotin-crystals are present in the tissue of the leaf in species of *Jussiaea*, *Godetia* and *Fuchsia*. Sclerenchyma is developed in the **veins** of the leaf in certain species of *Fuchsia*, but is otherwise absent.

Grosse also examined the structure of the **wood** in the herbaceous genera, and found that as a general rule they show features identical with those which I demonstrated in the woody members of the Order, viz. narrow medullary rays, vessels with simple perforations, and wood-fibres bearing simple pits. Grosse, however, mentions the occurrence of a relatively small number of scalariform perforations in the vessels, in species of *Oenothera* and *Godetia*.

In many members of the Order the tissue of the **cork** includes both suberized and unsuberized (phelloid) cells, and in some cases (species of *Fuchsia*) there is a regular alternation of layers of cork-cells and phelloid-cells. These phenomena already give indication of the tendency to develop aerenchyma, a tissue which H. Schenck has observed also in *Epilobium hirsutum*, L. According to H. Schenck the aerenchyma in the aerotropic roots of *Jussiaea* is developed from the primary cortex, while according to Grosse it is subsequently increased by the development of an aerenchyma from the phellogen.

Interxylary phloem has recently been observed by J. E. Weiss in the stolons of *Epilobium angustifolium*, L., and in the root of E. *hirsutum*, L., and by Grosse in the root, in *Epilobium palustre*, L., further species of *Oenothera* and species of *Gaura* and *Lopezia*. According to Leisering, Chodat, and Frémont, the interxylary phloem no doubt invariably arises from the wood-parenchyma by a process of secondary differentiation (though in some cases it appears very soon after the development of the parenchyma from the cambium), and is not given off directly by the cambium on its inner side, as was formerly supposed.

The vascular bundles in the delicate lateral **roots** of *Trapa* show a very remarkable structure (Queva). The radial vascular system exhibits unipolar differentiation, i.e. it comprises only a single group of xylem and a single group of phloem—a type of structure which is unique among the Phanerogams. Both the wood- and bast-portions are very much reduced, the former consisting of a single trachea, the latter of 3–10 soft-bast elements.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 68 et seq.—[Meehan, Pet. glands in some Onagrar., Proceed. Acad. Nat. Sc. Philadelphia, 1886, pp. 349–50; abstr. in Just, 1886, ii, p. 705.]—Haberlandt, Spaltöffn. d. Wasserpfl., Flora, 1887, p. 103.—Lamounette, Liber interne, Ann. sc. nat., sér. 7, t. xi, 1890, pp. 261, 262.—J. E. Weiss, Korkbild., Denkschr. bot. Gesellsch. Regensburg, vi, 1890, p. ii et seq.—Grosse, Beitr. z. vergl. Anat. d. Onagrar., Diss., Erlangen, 1895, 67 pp.—[Parmentier, in Mém. Soc. d'émulation Doubs, 1896, p. 327; and in Le Monde, 1896, p. 29, and 1897, p. 178.]—Ramaley, Stem-anatomy of certain Onagrar., Bot. Gazette, xxii, 1896, p. 229.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 17.—Wollenweber, Anat. d. Schwimmbl., Diss., Freiburg i. Br., 1897, pp. 20–1.—Spanjer,

Wasserapparate, Bot. Zeit., 1898, i, p. 45.—Leisering, Interxylares Leptom, Diss., Berlin, 1899, pp. 29–30.—Minden, Wasserser. Org., Bibl. bot., Heft 46, 1899, p. 44.—Kearny, in Contribut. U. S. Nat. Herb., v, n. 5, 1900, p. 297.—[Guffroy, Papilles chez les Épilobes, Bull. internat. Géogr. Bot., 1901, p. 9.]—[Léveillé, Monogr. du genre *Oenothera* avec la collab. pour la partie anat. de Geoffroy, Le Mans, Fasc. 1, 1902, 138 pp., and Fasc. 2, 1905.]—Queva, Radicelles de la Mâcre, Comptes rendus, Paris, cxxxvi, 1903, 1. Sem., pp. 826, 827; see also Bull. Soc. d'hist. nat. Autun, xvi, 1903.—Theorin, Vaxttrichom., Arkiv for Bot., i, 1903, p. 160; iii, n. 5, 1904, p. 11; and iv, n. 18, 1905, pp. 19–20.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 184–7 and 209–10.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 64–6.—[Gerschon-Seliber, *Jussiaea repens*, Diss., Halle, 1905, 54 pp.; also in Nova Acta Acad. Leop., lxxxiv; abstr. in Bot. Centralbl., cii, p. 244.]—Günther, Anat. der Myrtifloren, Diss., Breslau, 1905, p. 27.—Netolitzky, Dikotyledonenbl. (Rhaphiden), 1905, pp. 39–52.—[For additional literature, see p. 1171].

SAMYDACEAE (pp. 376–378).

1. Review of the Anatomical Features. The stomata either have subsidiary cells, arranged according to the Rubiaceous or Cruciferous type, or are merely surrounded by ordinary neighbouring cells. Schizogenous secretory cavities are found also in *Zuelania*; on the other hand, the earlier record of their occurrence in *Lunania* pro parte must be cancelled. As regards the hairy covering we may add that simple uniseriate clothing hairs with thin division-walls are of occasional occurrence, while unicellular Malpighian hairs are found also in *Banara guianensis*, Aubl., and stellate hairs also in *B. glauca*, Benth. Additional features which can be employed in specific diagnosis are as follow: the occurrence of a gelatinized epidermis in the leaf (only in the monotypic genus *Gerrardina*); the presence of hypoderm on the upper side of the leaf (species of *Abatia*, *Banara*, *Byrsanthus*, *Casearia*, *Euceraea*, *Homalium*, and *Zuelania*); idioblasts occupied by small clustered or solitary crystals in the epidermis of the leaf (besides occurring in species of *Homalium* and *Samyda*, also in species of *Bembicia*, *Casearia*, *Lunania*, *Ophiobotrys*, *Osmelia*, *Pyramidocarpus* and *Zuelania*); the occurrence of sclerenchymatous fibres in the mesophyll (species of *Calantica*, *Casearia*, *Homalium*, and *Zuelania*); and lastly, the peculiar silicified structures resembling cystoliths found in the mesophyll of *Homalium donquaiense*, Pierre.

2. Structure of the Leaf. Brändlein's recent investigations, which deal with the genera enumerated below[1], have furnished the following facts. The **epidermal cells** have straight or undulated lateral margins. The structure of the cuticle may frequently be compared with the markings on an etched glass plate, so that in these cases we may describe it as 'etched'; but striation and granulation also occur. The outer and inner walls vary in thickness, the latter occasionally presenting a swollen appearance, although they are gelatinized only in *Gerrardina foliosa*, Oliv. Marginal pits are not uncommon, and the same statement applies to the occurrence of relatively thin secondary division-walls, both horizontal and vertical. The surface-view of the epidermis is particularly striking in (*a*) the epidermis of the leaf of *Banara brasiliensis*, Benth. (owing to the penetration of the thick cuticle into the lateral walls in the form of strongly developed wedge-shaped ridges), (*b*) the lower epidermis of *Banara portoricensis*, Krug et Urb. (here the stomata with their thin-walled subsidiary cells appear as islands in the remaining tissue, which has thick and pitted walls), and (*c*) the epidermis of *Casearia densiflora*, Benth. (the lateral walls of which appear thin at a high focus, being provided with peculiar lobes, which are cuneate and have a narrow base and an

[1] These genera are: Tribe 1: Casearieae: *Casearia, Zuelania, Osmelia, Euceraea, Lunania, Tetrathylacium, Ophiobotrys, Samyda*; Tribe 2: Banareae: *Banara, Pyramidocarpus*; Tribe 3: Abatieae: *Abatia, Aphaerema*; Tribe 4: Homalieae: *Calantica* (incl. *Bivinia*), *Gerrardina, Dissomeria, Homalium, Byrsanthus, Bembicia.*

emarginate apex; at a low focus, on the other hand, they appear straight, and are rather thick and pitted). The occurrence of **hypoderm** has already been mentioned above; an enumeration of the species in which it is found is given below[1]. The hypoderm for the most part consists of a single layer of cells, although it is composed of three or four layers in *Homalium tomentosum*; it is confined to the upper side of the leaf. In *Euceraea nitida* the cells of the hypoderm, as well as the majority of the cells of the spongy tissue, are provided with hippocrepiform thickenings on the side facing the middle of the transverse section of the leaf. In some species of *Casearia* and *Lunania* small numbers of **stomata** occur on the upper side of the leaf. The Cruciferous type is distinctly differentiated in *Osmelia*, and the Rubiaceous type in *Abatia* (here occasionally ill-defined), *Banara*, *Bembicia*, *Byrsanthus*, *Calantica*, *Casearia*, *Dissomeria*, *Euceraea*, *Homalium*, *Samyda* and *Zuelania*. The structure of the leaf varies from bifacial to centric. The palisade-tissue consists of one or more layers. In *Abatia* there is invariably a single layer of palisade-tissue, which exceeds the spongy tissue in thickness. An indication of arm-palisade-tissue has been observed in the third palisade layer of *Casearia arguta*, H. B. K., while the cell-walls in the lowest palisade layers of the centric **mesophyll** of *C. corymbosa*, H. B. K. show peculiar sinuations appearing as ridges and giving rise to 'pseudo-pits.' In *Homalium racemosum*, Jacq. the lowest layer of the mesophyll presents a palisade-like differentiation and is developed in the form of conjugate parenchyma composed of short cells. The intercellular spaces of the spongy tissue vary in size, and the walls of the cells are thickened to a varied extent. In many species of *Lunania* the upper layers of the spongy tissue are rather strongly thickened and filled with brown contents, so that they form a kind of middle layer in the leaf. Peculiar silicified protuberances resembling cystoliths occur in *Homalium donquaiense*, where they are found especially in the palisade-tissue and correspond with one another in neighbouring cells. The vascular system of the **veins** is in most cases provided with a thick ring of sclerenchyma (the chief exceptions being *Abatia* and *Apharema*, which have little or no sclerenchyma). The sclerenchyma of the veins occasionally exhibits well-marked stratification of the wall (species of *Casearia* and *Homalium*) or consists of an outer envelope and a detached thickening layer. In the species enumerated below[2] the sclerenchyma of the veins branches off into the mesophyll to a varying extent. These spicular fibres also occasionally show well-marked stratification; in some cases they penetrate as far as the epidermis and may even continue their course beneath the latter. Brändlein observed vertical transcurrence of the smaller veins (lateral veins of the third order), which in some cases are provided with perfect plates of sclerenchyma, in species of *Abatia*, *Banara*, *Byrsanthus*, *Calantica*, *Casearia*, *Homalium* and *Samyda*.

The following details may be added regarding the **hairy covering**. Unicellular clothing hairs, which for the most part have thick walls and narrow lumina, have been recorded in the genera *Abatia*, *Aphaerema*, *Banara*, *Bembicia*,

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[1] The species are: *Abatia tomentosa*, Mart. (locally); *Banara guianensis*, Aubl. (locally); *Byrsanthus* sp. (Demeuse, Congo); *Casearia Bule*, Gilg, *C. comocladifolia*, Vent., *C. corymbosa*, H. B. K., *C. glomerata*, Roxb., *C. graveolens*, Dalz., *C. ilicifolia*, Vent., *C. lucida*, Tul., *C. Melistaurum*, Spreng., *C. mollis*, K. Sch. var. *glabra*, K. Sch., *C. nitida*, Jacq., *C. rubescens*, Dalz. (locally), *C. tomentosa*, Roxb., *C. Zenkeri*, Gilg; *Euceraea nitida*, Mart.; *Homalium Barandae*, Vid., *H. brevipedunculatum*, Scott-Ell., *H. Deplanchei*, Warb., *H. macropterum*, Gilg, *H. tomentosum*, Benth., *H. vitiense*, Benth., *H. Zenkeri*, Gilg; *Zuelania crenata*, Griseb., *laetioides*, A. Rich.

[2] *Calantica cerasifolia*, Tul.; *Casearia attenuata*, Rusby, *C. longicuspidata*, Gilg, *C. Selloana*, Eichl. (short fibres), *C. sylvestris*, Sw.; *Homalium brevipedunculatum*, Scott-Ell., *H. micranthum*, O. Hoffm., *H. microphyllum*, O. Hoffm., *H. paniculatum*, Benth., *H. Parkeri*, Bak. (short fibres), *H. urceolatum*, Scott-Ell.; *Zuelania laetioides*, Rich. (short fibres).

Calantica, Casearia, Euceraea, Homalium, Osmelia, Samyda, Tetrathylacium and *Zuelania*, while uniseriate hairs which are septate by means of relatively thin division-walls occur in species of *Casearia, Samyda* and *Zuelania*. The trichomes of *Banara guianensis*, Aubl. show all transitions between ordinary unicellular hairs and Malpighian hairs with equal arms. Diverse types of tufted hairs having two or more ray-cells with narrow lumina are found also in *Abatia boliviana*, Britt., *A. parviflora*, Ruiz et Pav., *Banara glauca*, Benth., and certain Central and South American species of *Casearia* belonging to the section *Pitumba*. In the two species of *Abatia* just named the unicellular and tufted hairs are accompanied by other types of tufted hairs, which have a longer, multiseriate shaggy stalk; the protrusion of a certain number of the superficial cells of the stalk of these trichomes into rays leads to the production of candelabra-hairs.

There is no **oxalate of lime** in the leaf in *Abatia, Aphaerema, Banara pyramidata*, Rusby and *Casearia attenuata*, Rusby. Small crystal-idioblasts are found in species of many genera [1]; they occur either in both upper and lower epidermis or only in the one or the other and are either isolated or arranged in rows or groups; in most cases each of them contains a clustered crystal, rarely a solitary crystal (the presence of solitary crystals is indicated in the list below by the abbreviation cr.). The crystals are occasionally enclosed in an envelope of cellulose after the manner of Rosanoff's crystals, or they may be suspended from beams of cellulose. Other noteworthy features are: the occurrence of complete layers of cells containing clustered crystals in the mesophyll (species of *Casearia* and *Homalium*); the occurrence of relatively large idioblasts with clustered crystals (species of *Casearia*), and the presence of cells exhibiting one-sided thickening and enclosing solitary crystals ('cristarque'-cells), in association with the sclerenchyma in the veins of the leaf (species of *Casearia* and *Homalium*).

Secretory cavities have been demonstrated in *Casearia* pro parte, *Euceraea, Samyda* and *Zuelania*. Although Bokorny and Warburg record secretory cavities in *Lunania*, Brändlein did not meet with these or any other types of secretory organs in any of the seven species which he examined. The earlier statement as to the occurrence of secretory cavities in *Osmelia* (according to Warburg) also requires confirmation, since they are absent in *Osmelia Maingayi*, King, according to Brändlein. According to Brändlein (cf. the earlier statements), all the species [2] of the genus *Casearia* belonging to the section *Piparea* (with the exception of *C. eriophora*, Wr.), as well as *C. cuspidata*, Gilg and *C. rubescens*, Dalz. (which belong to the section *Pitumba*), are characterized by the absence of secretory cavities. Brändlein states that the secretory cavities invariably have a distinct epithelium. Their yellowish and strongly refractive contents are soluble in alcohol, so that they are of the nature of resin. In *Casearia sylvestris*, Sw. secretory cells occur in the mesophyll side by side with the secretory cavities.

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[1] viz.: *Bembicia axillaris*, Oliv.; *Casearia bicolor*, Urb., *C. Bule*, Gilg, *C. comocladifolia*, Vent., *C. corymbosa*, H. B. K., *C. dentata*, Eichl. (cr.), *C. esculenta*, Roxb., *C. glomerata*, Roxb., *C. graveolens*, Dalz., *C. guianensis*, Rusby, *C. hirta*, Sw., *C. ilicifolia*, Vent., *C. Lobbiana*, Turcz., *C. macrophylla*, Vahl, *C. Melistaurum*, Spreng., *C. mollis*, K. Sch. var. *glabra*, K. Sch., *C. oblongifolia*, Camb., *C. obovata*, Poepp., *C. ramiflora*, Vahl, *C. rubescens*, Dalz., *C. tomentosa*, Roxb., *C. Vareca*, Roxb., *C. Zenkeri*, Gilg; *Homalium densiflorum*, Benth. (cr., side by side with clustered crystals), *H. foetidum*, Benth., *H. pedicellatum*, Benth., *H. racemosum*, Jacq., *H. Racoubea*, Sw.; *Lunania cuspidata*, Warb., *L. divaricata*, Benth., *L. dodecandra*, Wright, *L. parviflora*, Spruce, *L. racemosa*, Hook., *L. Sauvalii*, Griseb.; *Ophiobotrys Zenkeri*, Gilg; *Osmelia Maingayi*, King; *Pyramidocarpus Blackii*, Oliv.; *Samyda glabrata*, Sw., *S. grandiflora*, Griseb., *S. rosea*, Sims., *S. serrulata*, L.; *Zuelania crenata*, Griseb., *Z. laetioides*, Rich.

[2] The species are: *Casearia Brighami*, Wats., *C. Commersoniana*, Camb., *C. densiflora*, Benth., *C. dentata*, Eichl., *C. javitensis*, H. B. K., *C. laetioides*, Warb., *C. laurifolia*, Benth. (examined by Harms) *C. Maximiliani*, Eichl. and *C. Spruceana*, Benth.

3. Structure of the Axis. Regarding the occurrence of a composite and continuous ring of sclerenchyma, which also includes cells with U-shaped thickening, in the **pericycle** in species of *Casearia*, *Homalium* and *Samyda*, as well as of an interrupted ring in the pericycle in species of *Banara* and *Casearia*, see also Pitard, loc. cit.

Literature: Elfstrand, Heilpfl., Ber. deutsch. pharm. Gesellsch., 1897, p. 314.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 67-92.—[Pitard, Astéropéiées, Act. Soc. Linn. Bordeaux, lviii, 1903, p. lii et seq.]—Brandlein, Syst.-anat. Untersuch. d. Bl. der Samydaceen, Benth. et Hook., Diss., *Erlangen*, 1907, 69 pp.

TURNERACEAE (pp. 381–383).

Literature: Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 92.

PASSIFLORACEAE (pp. 383–388).

2. Structure of the Leaf. Papillae on the lower side of the leaf are found also in *Passiflora trifasciata*, Lem. (Knothe). Jumelle has recently also demonstrated internal **secretory receptacles** (see p. 385) in the axis and leaf of the newly established species, *Ophiocaulon Firingavelense*, Dr. de Cast. He describes them throughout as secretory cells, and states that they give rise to the wax-like or more properly (as he points out) resinous masses, which are repeatedly mentioned by systematists in their descriptions as covering the different parts of the axis in the species of *Ophiocaulon*.

Extrafloral **nectaries** are, according to Harms, present on the leaves also in *Paschanthus*, *Hollrungia* and *Tetrastylis*.

Literature: Aufrecht, Extraflor. Nekt., Diss., Zürich, 1892, p. 29 et seq. (*Passiflora coerulea*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 39 and 77.—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 14.—Jumelle, Passiflore à résine, Comptes rendus, Paris, cxxxvii, 1903, 2 Sem., pp. 206-8. —Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 109.—Paoli, Eterofillia, Nuovo Giorn. bot. Ital., xi, 1904, p. 216.—[Harms, in Natürl. Pflanzenfam., Erg.-Heft ii, 1907, p. 234.]

PAPAYACEAE (pp. 388, 389).

Literature: A translation of Schacht's paper will be found in Ann. sc. nat., ser. 4, t. viii, 1857, p. 164 et seq. and pl. vii, viii.—Molisch, Milchsaft u. Schleimsaft, 1901, p. 60.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 30–1 (*Carica*).

CUCURBITACEAE (pp. 389–397).

1. Review of the Anatomical Features. Glandular hairs with relatively long stalks are also found in this Order. Extrafloral nectaries are present on the leaves in certain species. The bundles of intraxylary phloem become secondarily changed into inversely orientated vascular bundles also in certain species of *Coccinia*, *Cucurbita*, *Kedrostis* and *Melothria*. In the older parts of the axis of *Actinostemma biglandulosum*, *A. racemosum* and *Momordica Charantia* secondary vascular bundles are developed from a secondary meristem arising in the endodermis.

2. The Structure of the Leaf in the Japanese species[1] has recently been examined in detail by Yasuda. The **epidermal cells** in these species are often of large size (the largest being .07 mm. in diameter in *Gymnostemma*

[1] viz. species of the genera: *Actinostemma*, *Benincasa*, *Citrullus*, *Cucumis*, *Cucurbita*, *Gymnostemma*, *Lagenaria*, *Luffa*, *Melothria*, *Momordica*, *Schizopepon*, *Trichosanthes*. The species in question are mentioned in the text above.

cissoides), and have straight or undulated lateral margins. In *Trichosanthes cucumeroides* the epidermal cells on the upper side of the leaf are drawn out into blunt conical papillae. The **stomata** are either present on both sides (varying in number on the upper surface) or are confined to the lower side of the leaf. We may add that the stomata on the stem are commonly situated at the apex of raised pedestals, formed by the epidermal cells (*Benincasa cerifera*, *Cucurbita Pepo*, &c.). For the occurrence of water-pores in the Cucurbitaceae, see Spanjer, loc. cit. According to Yasuda, the nature of the vascular system of the **midrib** may be advantageously employed for systematic purposes. He mentions the following types: A single vascular bundle in *Actinostemma racemosum* and *Schizopepon bryoniaefolius*; two vascular bundles, viz. a large one with a small strand above it, in *Melothria japonica*; one large bundle and two small lateral strands in *Gymnostemma cissoides*; three vascular bundles, viz. a large one and two small bundles situated vertically above the former, in *Benincasa cerifera*, *Cucumis sativus* and *Lagenaria vulgaris*; four bundles, arranged to form an almost right-angled cross, the lowest bundle being the largest, in *Momordica Charantia*, species of *Luffa* and *Trichosanthes*; seven vascular bundles forming a ring, the largest bundle being situated below while the remaining strands above become successively smaller and show a symmetrical arrangement, in *Citrullus vulgaris* and *Cucurbita Pepo*. Yasuda met with **oxalate of lime** only in the older stems; it is specially abundant in *Momordica Charantia*, where it occurs in the form of solitary crystals of diverse shape. In the **hairy covering** Yasuda distinguishes uniseriate clothing hairs, which are pointed or blunt, and external glands with stalks of varying length. He found the following types of glands: shortly stalked glandular hairs with a multicellular ovate head, in all the species; glands with a long stalk and a multicellular ovate head, in species of *Benincasa*, *Citrullus*, *Cucumis*, *Cucurbita*, *Lagenaria*, *Luffa*, *Momordica*, and *Trichosanthes*; glands with a long stalk and a head showing a special type of structure, the head being unicellular in *Trichosanthes cucumeroides*, bicellular by means of a transverse wall in *Cucurbita Pepo*, and lastly, multicellular with the two uppermost cells drawn out into blunt processes, in *Benincasa cerifera*.

In connexion with the subject of glandular hairs we may notice that extrafloral **nectaries** occur on the leaves in species of *Abobra*, *Adenopus*, *Alsomitra*, *Bryonia*, *Cephalandra*, *Cucurbita*, *Feuillea*, *Lagenaria*, *Luffa*, *Momordica*, *Sphaerosicyos*, *Trianosperma* and *Trichosanthes*; they are found either on the entire lower surface or are restricted to the bases of the leaves; in some cases they are also present on the sepals and bracts, the latter being sometimes completely transformed into nectaries (see Dutailly and Delpino, ll. cc.). These nectaries have long been known to systematists and biologists, but have not yet been closely examined. In the same way the 'folia subtus glandulosa' mentioned by Bentham and Hooker in species of *Cephalandra* and *Trianosperma* require detailed investigation; possibly they are merely due to the external glands.

Internal **secretory receptacles** have not as yet been recorded in this Order. Hallier, however, informs me, that he has seen an exudation of latex from a fruit of *Trichosanthes*, which had been cut open; so that *Trichosanthes* may in the first place be further investigated for the occurrence of secretory organs.

3. Structure of the Axis. We may add the following details regarding the occurrence of **bicollateral vascular bundles** in the Cucurbitaceae. According to Baranetzky a cambium, which produces woody tissue externally, appears at the outer margin of the inner soft bast in *Cucurbita perennis* (=*C. foetidissima*, Kth. ex Syn.), *Bryonia abyssinica* (=*Coccinia abyssinica*, Cogn.), *Rhynchocarpa dissecta* (= *Kedrostis africana*, Cogn.) and *Zehneria suavis* (=*Melothria punctata*, Cogn.). The vascular bundles thus produced are situated at the periphery

of the pith, and exhibit inverse orientation of the wood and bast; even in the thicker stems, however, they are not found in all parts of the transverse section. We may further note that the intraxylary phloem in some cases (e. g. in *Actinostemma biglandulosum*, see below) only appears at a late stage. This leads us to consider the anomaly recorded by Fries in the older stems of *Siolmatra brasiliensis*, Baill., which ultimately results in the appearance of inversely orientated medullary bundles of wood and bast, devoid of vessels. *Siolmatra brasiliensis*, like *Alsomitra*, &c., has ordinary collateral vascular bundles. Secondarily, however, a zone of cambium, which is at first interrupted, but subsequently becomes continuous, is developed at the margin of the pith; this cambial zone first produces groups of phloem internally and later groups of libriform externally.

Siolmatra, like the other members of the Order, shows two rings of vascular bundles in the transverse section of the stem. Of these the bundles of the inner ring are approximated in pairs, while those of the outer ring are inserted in the broad primary medullary rays, separating the paired bundles of the inner ring from one another; the outer bundles are divided into two lamellae, the inner ends of which are joined together so that they appear like the arms of a V, which is open towards the outside.

According to Yasuda, the **wood** contains vessels with a diameter of ·14–·5 mm., and formation of tyloses is of common occurrence.

In young parts of the axis the **pericycle** contains a closed ring of sclerenchyma composed of fibrous cells, but, according to Yasuda and Pitard, this ring becomes split open at later stages. In older stems, according to Yasuda, fibrous sclerenchyma is occasionally found also on the inner side of the vascular bundles. Secondary sclerenchyma, composed of short cells, is moreover commonly developed on the inner side of the primary sclerenchyma, e. g. in species of *Actinostemma*, *Citrullus*, *Gymnostemma*, *Luffa*, *Melothria*, *Momordica*, and *Trichosanthes*. In the species of *Trichosanthes* the secondary sclerenchyma in the older stem forms a ring, which is, however, not complete.

The outer portion of the **primary cortex** frequently contains well-differentiated collenchyma.

Yasuda observed formation of **cork** on the outer side of the sclerenchymatous ring in the species of *Trichosanthes*.

A central cavity often appears in the body of the **pith**, sometimes (*Benincasa cerifera*, *Cucurbita Pepo*, *Lagenaria vulgaris*) even in young stems.

To A. Fischer's synopsis of the distribution of **sieve-tubes** in the Cucurbitaceae we may add that according to Yasuda entocyclic and commissural sieve tubes occur also in species of *Actinostemma*, *Gymnostemma*, *Momordica*, *Schizopepon* and *Trichosanthes*.

The following details may be added regarding the **anomalous structure** of the axis mentioned above as occurring in species of *Actinostemma* and *Momordica*. The structure of the stem of *Actinostemma biglandulosum* may first be considered (according to Wallace). In the young axes there are two rings of five bundles each, the bundles alternating with one another. The inner ring consists of three collateral bundles with wood and bast and two phloem-bundles, the outer ring of five collateral bundles of wood and bast. At a later stage the bundles of both rings become bicollateral, the phloem-strands having in the meantime developed into collateral vascular bundles. In this case therefore the intraxylary soft bast appears at a relatively late stage. At the base of older stems accessory vascular bundles are developed from a meristem arising in the endodermis, i.e. immediately external to the ring of pericyclic sclerenchyma. These vascular bundles show a radial arrangement and are situated on the outside of the primary bundles; they ultimately become bicollateral, and then undergo increase in the normal way by means of a cambium; to the naked eye they appear as ribs.—Yasuda records the development of such secondary vascular bundles, which are visible externally as ribs, and

are situated on the outer side of the sclerenchymatous ring also in old stems of Actinostemma racemosum and *Momordica Charantia.*

Tondera has published at length on the structure of the **tendrils**; he utilizes the fact that the stalk of the tendril resembles the petiole in containing only a single vascular ring, formed by the leaf-trace bundles situated in the angles of the stem, to support the view that the tendrils are metamorphosed leaves. For the sensitive pits on the tendrils, see Haberlandt, loc. cit.

Literature: Dutailly, Écailles glandulif., Bull. Soc. bot. Linn. de Paris, n. 6, 1875.—[Arthur, Trichomes of *Echinocystis lobata*, Bot. Gazette, vi, 1881, pp. 180–3, 1 pl.]—Haberlandt, Einkapselung d. Protopl., Sitz.-Ber. Wiener Akad., xcviii, Abt. 1, 1889, pp. 190–8 and Tab.—Lamounette, Liber interne, Ann. sc. nat., ser. 7, t. xi, 1890, pp. 249–52.—[Drobnig, Wurzelknollen, Diss., Rostock, 1892, p. 29 et seq. (*Thladiantha*, *Ecballium*).]—Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Elfstrand, Heilpfl., Ber. deutsch. pharm. Gesellsch., 1897, p. 293 (*Trianosperma*).—Spanjer, Wasserapparate, Bot. Zeit., 1898, i, p. 53.—Baranetzky, Faisc. bicollat., Ann. sc. nat., sér. 8, t. xii, 1900, pp. 274–8 and 301–4.—Wallace, Stem-structure of *Actinostemma biglandulosum*, Ann. of Bot., xiv, 1900, pp. 639–45 and pl. xxxiv.—Borzi, Apparato senso-mot. dei cirri delle Cucurbit., Atti R. Accad. Lincei, Rendiconti, x, 1. Sem., 1901, pp. 395–400.—Delpino, Org. caratterist. di alc. Cucurbit., Mem. Accad. Sc. Bologna, Ser. 5, ix, 1901–1902, p. 383 et seq. and Tab. i–iii.—Haberlandt, Sinnesorg., 1901, pp. 126–32 and Tab. v.—Pitard, Faisc. libér. tert. d. tiges des Cucurbit., Act. Soc. Linn. Bordeaux, lvi, 1901, pp. civ–cviii; and Péricycle, Thèse, Bordeaux, 1901, pp. 46, 47.—[Pollock, Fibrovasc. bundles in the root and hypocotyl in *Echinocystis lobata*, Report Michigan Acad. Sc., iii, 1901, pp. 40–2.]—[Yasuda, Comp. anat. of the Cucurbit. etc. (Japanese), Bot. Magaz. Tokyo, xv, 1901, pp. 88–91.]—[Borzi, Apparato senso-mot. etc., Contribuz. Ist. bot. Palermo, iii, 1, 1902, pp. 119–76.]—Tondera, Gefässbündelsyst. d. Cucurbit., Sitz.-Ber. Wiener Akad., cxii, Abt. 1, 1903, pp. 23–59 and Tab. i–v.—Yasuda, Comp. anat. of the Cucurbit. etc., Journ. Coll. of Sc. Imp. Univ. Tokyo, xviii, 1903, 56 pp. and 5 pl.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 205–6.—Faber, Bikoll. Gefässb. von *Cucurbita Pepo*, Ber. deutsch. bot. Gesellsch., 1904, pp. 296–303, and Tab. xvi, xvii.—[Nemec, Stärkescheide d. Cucurbit., Bull. int. Acad. sc. Bohême, ix, 1904, 12 pp.]—[Bernet, Obs. anat. nouv. sur la tige des Cucurbit., Bull. Herb. Boiss., 2e ser., v, 1905, p. 312; and Comptes rendus Soc. bot. Geneve.]—Fries, Zwei südamerikan. Lianen, Botaniska Studier tillagn. Kjellman. Upsala, 1906, pp. 89 and especially 96 et seq.

BEGONIACEAE (pp. 398–406).

Literature: Keller, Luftwurzeln, Diss., Heidelberg, 1889, pp. 17, 18.—C. de Candolle, Infloresc. épiphylles, Mém. Soc. de phys. et d'hist. nat. Genève, 1890, vol. suppl., sep. copy, p. 20 et seq.—Jonsson, Anat. Bau d. Bl., Acta Univ. Lund., xxxii, 2, 1896.—Minden, Wassersez. Org., Bibl. bot., Heft 46, 1899, p. 45.—Rechinger, Trichome d. Gesneriaceen, Österr. bot. Zeitschr., 1899, sep. copy, p. 2, foot-note 2.—Haberlandt, Lichtsinnesorg., 1905, p. 75.—Theorin, Vaxttrichom., Arkiv för Bot., iv, n. 18, 1905, p. 8.

DATISCEAE (p. 406).

Regarding the water-pores, see Spanjer, loc. cit.

Literature: Spanjer, Wasserapparate, Bot. Zeit., 1898, 1, p. 54.—Montemartini, Studio anat. sulla *Datisca cannabina*, Annali di Bot., iii, 1905, pp. 101–12 and Tab. xi, xii.

CACTEAE (pp. 406–415).

Regarding the differentiation of the **hypoderm**, see also Preston, loc. cit. He records a hypoderm of 6–7 layers in *Echinocactus Wislizeni*, Engelm., and one of 12–14 layers in *Cereus giganteus*, Engelm.; he also mentions the occurrence of oxalate of lime in the hypoderm in *Mammillaria Grahami*, Engelm., *Opuntia arborea*, Engelm., *O. fulgida*, Engelm. and *O. phaeacantha*, Engelm. In *Opuntia fulgida* and *O. leptocaulis*, DC. the epidermis contains crystals which in the case of *O. leptocaulis* are found in special idioblasts.

The peripheral **ground tissue** is frequently differentiated as palisade-tissue, e.g. in *Cereus giganteus*.

According to Preston's statements on the structure of the **wood** the

characteristic elementary organs, described under the name of tracheids, occasionally occur also in the genus *Cereus* (*C. Fendleri*, Engelm.). In the species just named narrow zones composed of spiral vessels alternate in transverse section with broader zones consisting of tracheids with a flat spiral band. It remains doubtful whether these tracheids possess a lining layer of protoplasm and a nucleus (cf. p. 410) during the whole of their existence or whether such contents are present only in the young condition (see Darbishire, loc. cit.).

To the remarks made on p. 411 on the morphological nature of the **thorns** we may add that according to Rudolph the thorns of *Opuntia missouriensis* are neither leaves, nor emergences, but merely simple trichomes.

From the systematic-chemical point of view the demonstration of saponin in *Cereus gummosus*, Engelm. is interesting (Heyl).

Literature: Keller, Luftwurzeln, 1889, pp. 33-5.—Mittmann, Pflanzenstacheln, Verh. bot. Ver. Mark Brandenburg, 1889, p. 60—Barber, Corky excresc., Ann. of Bot., vi, 1892, p. 166.—Lothelier, Épines, These, Paris, 1893, p. 41.—Ganong, in Bot. Gazette, 1895, pp. 213-21.—Matteucci, Placche sugherose, Nuovo Giorn. bot. Ital., 1897, p. 224 et seq.—K. Schumann, Gesamtbeschr. d. Cacteen, 1899, pp. 13-15.—Preston, Root-system of certain Cacteae, Bot. Gazette, 1900, pp. 348-51.—Heyl, Alkaloide u. Saponine in Cact., Archiv d. Pharm., 239, 1901, p. 471.—Preston, Struct. studies on Southwestern Cact., Bot. Gazette, 1901, pp. 35-55 (species of *Cereus*, *Echinocactus*, *Mammillaria*, *Opuntia*).—[Bray, Plants of the Sotol region, Bull. Torrey Bot. Club, xxx, 1903, p. 621 et seq.]—Rudolph, Stachelbild. bei Cact., Oesterreich. bot. Zeitschr., 1903, pp. 105-9 and Tab. i.—Darbishire, *Mammillaria elongata*, Ann. of Bot., 1904, pp. 375-416 and pl. xxv, xxvi.—Porsch, Spaltoffnungstypus, Jena, 1905, pp. 119-23 and Tab. iv.—[Arcangeli, *Cereus peruvianus*, Atti del Congresso dei Naturalisti ital., Milano, 1906, p. 403 et seq.]

FICOIDEAE (pp. 415-419).

According to Gulliver, styloids occur also in species of *Mesembryanthemum*.

Literature: Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iii, p. 472.—Baccarini e Scillamà, *Glinus lotoides*, Contribut. Ist. bot. Palermo, ii, 1898, pp. 83-129 and Tab. ix-xiv.—W. Meyer, Vergl. Anat. d. Caryophyllac., etc. Diss., Göttingen, 1899 (*Telephium*).—Brenner, Fettpfl., Flora, 1900, pp. 398-402 (*Mesembryanthemum*).—Josting, in Beih. z. Bot. Centralbl., xii, 1902, p. 141 (*Telephium*).—Kearny, in Contrib. U. S. Nat. Herb., vi, 1900, p. 302 (*Sesuvium*).—[Bergamasco, Biol. delle Mesembr., Bull. Orto bot. Napoli, 1904, p. 165 et seq.; abstr. in Just, 1904, i, p. 715.]—[Pilger, Neue Gatt. der Aizoaceae, in Engler, Bot. Jahrb., xl, 1908, pp. 396, 397 (*Gliscnrothamnus*).]

UMBELLIFERAE (pp. 419-426).

1. To the list of anomalous structures enumerated at the end of the REVIEW OF THE ANATOMICAL FEATURES we may add the fission of the xylem-mass in the axis and root of *Azorella Selago*, Hook. fil. The very rare occurrence of glandular hairs may also be mentioned on Süssenguth's authority.

2. STRUCTURE OF THE LEAF. A one-layered hypoderm is developed above the lower **epidermis** in *Bupleurum petraeum* (according to Briquet) and *B. graminifolium*, Vahl (according to David). The upper epidermis is papillose in *Bupleurum falcatum*, L. and *B. montanum* (David); it consists of large cells in *Hermas villosa* (Duboule). The mechanical elements in the veins of the leaf are collenchymatous or sclerenchymatous.

For the structure of the septate phyllode-like leaves of *Oxypolis filiformis*, Britt., see Rennert; for the structure of the leaves of *Azorella*, see Ternetz, and for those of *Hermas*, see Duboule, ll. cc.

In connexion with the subject of oxalate of lime (p. 421) we may add that according to Ad. Meyer and Nestel the leaves of *Aethusa Cynapium*, L., *Conium maculatum*, L., *Seseli Libanotis*, Koch and *Trinia glauca*, Reichb. contain small, sometimes plumose excretions, which occur both in herbarium- and alcohol-material. Ad. Meyer considers these masses to be hesperidin, while Tschirch looks upon them as consisting of a new substance of unknown nature.

As regards the **hairy covering** we may note that Bourdin figures simple uniseriate clothing hairs in *Oenanthe globosa*, L., while Duboule records three-celled clothing hairs with a basal cell, a short stalk-cell and a long terminal cell in *Hermas gigantea*. Süssenguth states that he has observed small glandular hairs with a head composed of 2–4 cells on the lower side of the leaf of *Pimpinella Saxifraga*.

3. Structure of the Axis. Among the species having **medullary vascular bundles** (cf. p. 424) we may include *Magydaris panacifolia*, Lge. (according to Kümmerle; this species has numerous bundles, which are either collateral or concentric with central phloem), as well as *Apium graveolens*, L. and *Hacquetia Epipactis*, DC. (according to Nestel).

According to Ternetz, *Azorella Selago*, as already mentioned above, exhibits fission of the **xylem-mass** in the older parts of the stem and in the roots. This anomaly is closely related to the anomalous structure of the root previously known to occur in certain species of *Oenanthe*, &c., and already described in section 4, p. 425 ('secondary transformation of the fibrovascular system into concentric vascular bundles'), although it has quite a distinct aspect in transverse section, especially in the older parts of the plant. The common features of both types of anomaly are the cleavage of the original fibrovascular system and the appearance of secondary meristems, producing wood and bast.

According to Ternetz, the fission of the xylem-mass in the axis of *Azorella Selago* takes place as follows. In the young axis the vascular bundles are loosely arranged in the normal way to form a ring. In the course of growth in thickness and the simultaneous development of cork, a process of disorganization is started in the parenchymatous ground-tissue and in the outer portions of the secondary cortex, both of which become partly transformed into a kind of complementary tissue; at the same time clefts are formed, which have an approximately radial course and also penetrate between the groups of wood in the direction of the pith. When the axis has attained a thickness of 5–6 mm., meristematic tissue commences to develop in the region of the xylem-mass, viz. along the radial clefts and on the inner side of the xylem-segments; this meristematic tissue gives rise to a parenchyma, which undergoes dilatation. The appearance of secondary meristems forming wood and bast in this parenchyma and their junction with the normal cambium of the vascular bundles then leads to the development of a kind of polystely; in consequence of further cleavage, however, this structure soon becomes disturbed and gives way to a maze of separate segments of wood and bast irregularly interwoven with one another.—We may also note that the xylem-mass of *Azorella* contains only 'annular and spiral vessels' and no reticulate or pitted vessels; apart from these vessels it consists solely of unlignified parenchyma.

4. Structure of the Root. In *Magydaris panacifolia* the older roots have a structure similar to that found in *Oenanthe crocata*, the transverse section showing two rings of concentric vascular bundles with central xylem. The mode of development of this structure is the same as in *Oenanthe*.

Literature: Ad. Meyer, Anat. Charaktere offiz. Bl. u. Kräuter, Abh. naturf. Gesellsch. Halle, xv, 1882, sep. copy, pp. 7–10.—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 72 et seq.—Costantin, Tiges d. pl. aquat., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 et seq. and pl. xvi.—Jadin, Org. sécrét., Thèse, Montpellier, 1888, p. 36 et seq.—K. Müller, Freie Gefässb. in den Blattstielen, Sitz.-Ber. naturf. Freunde Berlin, 1890, p. 131.—Lothelier, Épines, Thèse, Paris, 1893, p. 25 (*Eryngium*).—[Pohl, Pharmakognosie d. Umbellif.-Wurzeln, Lotos, xiv, 1894, pp. 89–98, 2 Tab.; abstr. in Just, 1894, i, p. 484.]—Bourdin, Ombellifères, etc., Anat. comp. de la feuille, Thèse, Montpellier, 1897, pp. 51–87.—[Briquet, Monogr. des Buplevres des Alpes maritimes, Bâle et Genève, 1897, 131 pp.]—Briquet, Théorie phyllodique, etc., Bull. Herbier Boissier, v, 1897, p. 235 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 17.—Duboule, Anat. comp. de la feuille dans le genre *Hermas*, Arch. sc. phys. et nat. Genève, sér. 4, t. vii, 1899, pp. 446–80 and pl. iv: also in Bull. Labor. de bot. gén. de Genève, ii, 1899, pp. 37–72.—Minden, Wassersez. Organe, Bibl. bot., Heft 46, 1899, p. 22 (*Berula*).—Schleichert, Xerophyten bei Jena, Naturwiss. Wochenschr., 1900, p. 449 (*Bupleurum*).—Thomas, Feuilles sout., Thèse, Paris, 1900.—David, Étude anat. du genre *Bupleurum*, Thèse, Paris, 1901, 95 pp.—[Goris, Wurzel von *Asa foetida*, Journ. de Pharm. et Chimie, 1901, n. 12; abstr. in Just, 1901, ii, p. 37.]—[Holm, *Erigenia bulbosa*, Americ. Journ. of Sc., xi, 1901, p. 63.]—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 39.—Knothe, Unbenetzb.

Bl., Diss., Heidelberg, 1902, p. 21.—*Kümmerle, Beitr. z.* Kenntnis d. Anat. d. Umbellif. (*Magydaris*), Novenytani Kozlemenyek. 1902, Hungarian, sep. copy, 18 pp.—[Petersen, Bladnerv. hos arter af slagten *Bupleurum*, Bot. Tidsskrift, xxvi, 1902, pp. 343-76.]—Ternetz, Morphol. u. Anat. d. *Azorella Selago*, Hook. f., Bot. Zeit., 1902, pp. 1-20 and Tab. i.—Modrakowski, Vergl. Untersuch. d. dem *Conium maculatum* ähnlichen Umbellif., *Zeitschr.* allg. österreich. Apothekerver., 1903, n. 45-50, sep. copy, 20 pp.—[Rennert, Phyllodes of *Oxypolis filiformis*, Bull. Torrey Bot. Club, xxx, 1903, pp. 403-11 ; abstr. in Bot. Centralbl., xcv, p. 247.]—Theorin, Vaxttrichom., Arkiv för Bot., i, 1903, p. 160.—Col, Faisceaux, Ann. sc. nat., ser. 8, t. xx, 1904, pp. 173-9.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot. *Heft 61, 1904, p. 66.*—Süssenguth, Behaarungsverh. d. Würzburger Muschelkalkpfl., Diss., Würzburg, 1904, pp. 32-5.—Nestel, Stengel- u. Blattanat. d. Umbellif., Diss., Zurich, 1905, 126 pp., 1 Tab.—Weberbauer, Vegetat. d. Hochanden Perus, in Engler, Bot. Jahrb., xxxvii, 1905, p. 60 et seq.—[For further literature, see p. 1172.]

ARALIACEAE (pp. 426-432).

1. REVIEW OF THE ANATOMICAL FEATURES. The recent investigations on the structure of the leaf and axis undertaken by Güssow[1] and Viguier[2] render a number of additions necessary. The superficial development of the cork in the stem and the frequent presence of collenchymatous tissue in the primary cortex are features characteristic of the Order. Oxalate of lime is excreted not only in the form of ordinary solitary and clustered crystals, but occasionally also in the form of prismatic crystals of varying size (epidermis of the leaf of *Astrotricha*) and of typical crystal-sand (*Apiopetalum*, *Boerlagiodendron*, *Motherwellia*, *Tetraplasandra*). According to Güssow, secretory cavities are found in the mesophyll also in species of *Cussonia*, *Eremopanax*, *Heteropanax*, *Kissodendron* and *Pseudosciadium*. As regards the hairy covering we may add that unicellular clothing hairs and typical external glands are wanting, that shaggy hairs occur also in species of *Kalopanax* and *Stilbocarpa*, and that small scale-like trichomes are found in *Oreopanax xalapensis*, Decne. et Planch. According to Güssow (although not in agreement with Viguier), medullary vascular bundles, showing varied orientation of wood and bast, are present not only in species of *Aralia* and *Arthrophyllum*, but also in species of numerous other genera. Certain species (especially those of *Oreopanax*), moreover, are distinguished by the possession of cortical vascular bundles ; for details on this point, see under the structure of the axis.

According to Viguier, the genus *Aralidium*, in which both Güssow and Viguier found no resin-canals, must be excluded from this Order. Special anatomical features recorded in this genus are : small cortical vascular bundles exhibiting normal orientation ; isolated groups of bast-fibres in the pericycle ; broad medullary rays in the wood, and bundles of medullary fibres.

2. The STRUCTURE OF THE LEAF is again bifacial in most of the species investigated by Güssow, but in some cases it merges into homogeneous-centric structure ; isolateral structure with palisade-tissue situated on both sides of the leaf has not been recorded in any member of the Order. Arm-palisade tissue occurs also in *Acanthopanax sessiliflorus*, Seem. and *Pseudopanax laetevirens*, Benth. et Hook. The intercellular spaces of the spongy tissue

[1] Güssow's investigations extend to the following genera, which are enumerated in the serial order of Harms' system : I. Scheffleréae : *Tupidanthus*, *Plerandra*, *Tetraplasandra*, *Reynoldsia*, *Pterotropia*, *Boerlagiodendron*, *Trevesia*, *Fatsia*, *Tetrapanax*, *Meryta*, *Schefflera*. *Oreopanax*, *Gilibertia*, *Hedera*, *Brassaiopsis*, *Gastonia*, *Polyscias*, *Kissodendron*, *Pseudopanax*, *Macropanax*, *Nothopanax*, *Cheirodendron*, *Astrotricha*, *Acanthopanax Kalopanax*, *Didymopanax*, *Heteropanax*, *Cussonia*, *Arthrophyllum*, *Eremopanax*. II. Aralieae : *Pentapanax*, *Motherwellia*, *Aralia*, *Stilbocarpa*, *Panax*, *Aralidium*, *Horsfieldia* (= *Harmsiopanax*), *Myodocarpus*, *Delarbrea*, *Porospermum*. III. Mackinlayeae : *Mackinlaya*, *Apiopetalum*, *Pseudosciadium*.

[2] Viguier's work is essentially concerned only with the differentiation of the vascular system and the distribution of the resin-canals in the axis and petiole ; his investigations were, however, also undertaken on material representing very numerous genera.

are usually small, although in some cases of large size. **Stomata** are rarely found on the upper side of the leaf and then only occur in small numbers (*Aralia humilis*, Cav., *Gastonia cutispongia*, Lam., *Tetrapanax papyrifer*, K. Koch). In certain species of *Macropanax*, *Schefflera* and *Tupidanthus*, the stomata are exceptionally numerous, so that the lower epidermis is formed entirely by the stomata with their subsidiary cells. The pairs of guard-cells either lie on a level with the epidermis or may be somewhat raised or a little sunk. Stomata having subsidiary cells arranged according to the Rubiaceous type were observed by Güssow also in species of *Aralia*, *Astrotricha*, *Cheirodendron*, *Echinopanax*, *Eremopanax*, *Fatsia*, *Gastonia*, *Mackinlaya*, *Nothopanax*, *Oligoscias* and *Psorospermum*. The old and new investigations (see below) have shown that the occurrence of **hypoderm** on the upper side of the leaf is a very widely distributed feature in the Araliaceae. On the other hand, papillose differentiation of the **epidermis** is not frequently found; to the previous records we may add the slightly papillose protrusions found on the upper side in *Reynoldsia sandwicensis*, A. Gray, on the lower side in *Polyscias sambucifolia*, Harms, and on both sides in *P. farinosa*, Harms, as well as the papillae present on the lower side of the leaf of *Pentapanax parasiticus*, Seem.; the latter resemble those of *Aralia canescens*. Güssow also failed to meet with gelatinization of the epidermis of the leaf in any member of the Order.

Güssow mentions the occurrence of tangential division-walls in the epidermis in *Nothopanax diversifolius*, Harms, and of a one-layered hypoderm, which is only developed locally, in certain species of *Arthrophyllum*, *Oreopanax* and *Polyscias*. He further records: a one-layered hypoderm, in *Arthrophyllum Blumeanum*, Zoll. et Moric., *A. diversifolium*, Bl. (sphalm. '*quinquefolium*'), *Cheirodendron Gaudichaudii*, Seem., *Cussonia spicata*, Thunb., *C. umbellifera*, Sond., *Delarbrea collina*, Vieill., *Didymopanax vinosus*, March., *Gastonia duplicata*, Pet.-Thouars, *Gilibertia laurifolia*, March., *Meryta microcarpa*, Baill., *Myodocarpus pinnatus*, Brongn. et Gris., *Nothopanax arboreus*, Seem., *Reynoldsia sandwicensis*, A. Gray, *Schefflera tomentosa*, Harms, *Tetrapanax papyrifer*, Koch: a 1–2-layered hypoderm, in *Cheirodendron platyphyllum*, Seem., *Eremopanax otopyrenus*, Baill., *Oreopanax Rusbyi*, Britt., *Schefflera Volkensii*, Harms; a 2-layered hypoderm, in '*Aralia trifoliata*,' *Didymopanax Morototoni*, Decne. et Planch., *Pterotropia kavaiensis*, Hillebr., *Tetraplasandra meiandra*, Hillebr.; a 2–3-layered hypoderm, in *Tupidanthus calyptratus*, Hook. f. et Th.; a 3-layered hypoderm, in *Apiopetalum velutinum*, Baill. (cells 7–8 times the size of the epidermal cells); a 4–5-layered hypoderm in *Gastonia cutispongia*, Lam.

Viguier mentions the occurrence of hypoderm also in the following species, which have not been named in the preceding paragraph: *Apiopetalum glabratum* (3–4-layered), *Cussonia vantsilana*, *Eremopanax Balansae* (2-layered), *Fatsia japonica* (locally), *Mackinlaya macrosciadea* (3-layered), *Mesopanax capitatum*, *Myodocarpus crassifolius*, *M. floribundus*, *Nothopanax simplex* (locally), *Oreopanax Sanderi* (1-layered), *O. xalapense* (2–3-layered), *Pseudopanax Lessonii*, *Pterotropia dipyrena*, *Schefflera Humblotiana* (situated on both sides, and composed of one or two layers of lignified cells), *Sciadopanax Grevei*, *Tieghemopanax Weinmanniae*; Holtermann also records hypoderm in *Heptapleurum emarginatum* (2–3-layered, as in *H. stellatum*).

Oxalate of lime is found not only in the form of clustered and ordinary solitary crystals, but also as crystal-sand and prismatic crystals. Cells containing crystal-sand have been observed in the mesophyll in *Apiopetalum velutinum*, Baill., *Boerlagiodendron Warburgii*, Harms, *Motherwellia haplosciadea*, F. v. Müll. and *Tetraplasandra meiandra*, Hillebr.; the crystal-sand is composed of fine grains, and includes clustered crystals in the species of *Boerlagiodendron* and *Tetraplasandra* just named. The clustered crystals found in the pith are occasionally grumose, while those in the mesophyll in some cases attain a considerable size. Ordinary solitary crystals are of much

more frequent occurrence than was formerly supposed. The epidermis of the leaf contains clustered crystals also in *Acanthopanax sessiliflorus*, Seem. and *Pseudosciadium Balansae*, Baill., the above-mentioned prismatic crystals in species of *Astrotricha*, and ordinary solitary crystals in *Eremopanax otopyrenus*, Baill., as well as in *Acanthopanax ricinifolius*, S. et Z., *Arthrophyllum diversifolium*, Bl. and *Kalopanax ricinifolius*, S. et Z. (in the last-named species in the epiderm is covering the veins of the leaf). Clustered crystals, lastly, are found also in the hypoderm in *Apiopetalum velutinum*, *Cheirodendron platyphyllum*, *Polyscias farinosa* and *Tupidanthus calyptratus*.

We have next to consider the **secretory canals** found in the veins of the leaf (see p. 428). According to Güssow, they are confined to the midrib also in *Acanthopanax pentaphyllus*, March., *Aralia dasyphylla*, Miq., *A. humilis*, Cav., *Cussonia spicata*, Thunb., and *Pentapanax angelicifolius*, Griseb., while they appear to be absent in the leaves of *Polyscias farinosa*, Harms, *P. sambucifolia*, Harms, *Pseudopanax laetevirens*, Benth. et Hook., and *P. valdiviensis*, Benth. et Hook. According to Güssow, secretory cavities, resembling those of *Gilibertia*, but of small size, are found in the mesophyll in *Cussonia umbellifera*, Sond., *Eremopanax otopyrenus*, Baill., *Heteropanax fragrans*, Seem., *Kissodendron australianum*, Seem. and *Pseudosciadium Balansae*, Baill.; they do not give rise to transparent dots[1]. *Gilibertia protea*, Harms (see p. 429), which differs from the other species of the genus in not having secretory cavities, is placed by Viguier in the new genus *Mesopanax*, which also includes certain species of *Oreopanax*.

The most important feature of the **hairy covering** is the absence of unicellular hairs and of typical external glands. Güssow records shaggy hairs (the terminal cells of which are, however, not glandular) in *Acanthopanax sessilifolius*, Seem., *Aralia nudicaulis*, L., *Kalopanax ricinifolius*, S. et Z. and *Stilbocarpa polaris*, Decne. et Planch. Two-armed hairs, like those of *Didymopanax longepetiolatus*, are found also in *D. Morototoni*, Decne. et Planch. and *D. vinosus*, March. According to Güssow, tufted and stellate hairs are widely distributed. Scale-like trichomes, having the same structure as the peltate hairs of *Hedera Helix*, but small and orange-coloured, occur in *Oreopanax xalapensis*, Decne. et Planch., while uniseriate clothing hairs, which have thin walls and are occasionally branched, are found in *Kalopanax ricinifolius*, S. et Z. Viguier's statements about the trichomes are too vague to demand further consideration.

The **petiole** (cf. p. 430) has recently been subjected to a very thorough investigation by Viguier. The normal vascular bundles of the petiole are generally arranged in a ring, rarely in the form of a horseshoe (as in *Pseudopanax* pro parte, or *Apiopetalum*). They are either quite distinct from one another or are united by an inner or outer ring of sclerenchymatous fibres; in some cases (as in *Tupidanthus*) they are embedded in a special ring of lignified parenchymatous tissue. The number of bundles is for the most part relatively large, but in *Astrotricha ledifolia* there are only three vascular bundles, which almost touch one another. In *Oreopanax* § *Digitatae*, and *Macropanax* the vascular bundles of the normal ring are alternately large and small. Other anatomical features of the petiole, which, besides those already named, are employed by Viguier for purposes of classification, are as follows: the occurrence of subepidermal collenchymatous tissue; cambial activity in the vascular bundles of the normal ring (particularly marked in *Delarbrea spectabilis*); the distribution and size of the resin-canals; the occurrence of a central lacuna; and lastly, the development, structure, number, and

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[1] Viguier (loc. cit.) does not mention these features.

arrangement of the medullary vascular bundles. As regards the latter we may note that in some cases there is only a small central bundle (e.g. in *Anomopanax* and *Pseudosciadium*); in other cases there is a ring of medullary bundles showing inverse orientation of the wood and bast (e.g. in *Aralia*, *Arthrophyllum*, *Kissodendron*, and *Pentapanax*), or a normally orientated ring of medullary bundles with the xylem-groups pointing inwards (e.g. in *Cussonia* and *Gamblea*) or medullary bundles showing an irregular arrangement of the wood and bast, and so on.

Viguier records medullary vascular bundles in the petiole in the following genera: *Anomopanax* (1 vascular bundle), *Apiopetalum* (some of the bundles inversely orientated, others irregularly arranged), *Aralia* excl. *A. ferox* (rachis containing a single ring of inversely orientated bundles), *Arthrophyllum* (single ring of inversely orientated bundles), *Boerlagiodendron*, *Brassaiopsis* (single ring of irregularly arranged bundles), *Cuphocarpus* (numerous irregularly arranged bundles), *Cussonia* (single ring of normally orientated bundles), *Didymopanax* (a few, more or less coalescent bundles), *Dizygotheca* (outer bundles inversely, inner bundles normally orientated, or two rings of inversely orientated bundles), *Eremopanax* (numerous scattered bundles in the petiole), *Gamblea* (single ring of normally orientated bundles), *Gastonia* (numerous bundles exhibiting varied orientation; some of them concentric with central phloem), *Giliberta* pro parte (a few small inversely orientated bundles), *Heteropanax* (rachis with a single ring of inversely orientated bundles, which are intercalated between the bundles of the normal ring), *Kissodendron* (single ring of inversely orientated bundles), *Mackinlaya* (irregularly and inversely orientated bundles), *Meryta* (numerous irregularly arranged bundles), *Mesopanax* (a few irregularly arranged bundles or a single ring of inversely orientated bundles), *Myodocarpus* (numerous irregularly arranged bundles, occasionally not prominently developed), *Octotheca* (like *Dizygotheca*), *Oreopanax* § *Digitatae* (single ring of inversely orientated bundles), *Pentapanax* (single ring of inversely orientated bundles), *Plerandra* (normally orientated bundles), *Polyscias* (few or many irregularly arranged bundles), *Pseudopanax* pro parte (three small normally orientated bundles), *Pseudosciadium* (one bundle), *Pterotropia* (one or two large bundles), *Schefflera* (one or two rings of inversely orientated bundles), *Sciadopanax* (a few small bundles), *Strobilopanax* (like *Meryta*), *Tetrapanax* (somewhat irregularly arranged bundles), *Tetraplasandra* (many irregularly arranged bundles), *Tieghemopanax* (numerous irregularly arranged bundles), *Trevesia* (some of the bundles inversely orientated), *Tupidanthus* (some of the bundles with varied orientation, others inversely orientated). On the other hand, Viguier states that medullary vascular bundles are absent in: *Acanthopanax*, *Aralia ferox*, *Astrotricha*, *Bonnierella*, *Cephalaralia*, *Cheirodendron*, *Delarbrea*, *Echinopanax*, *Fatsia*, *Gilibertia* pro parte, *Hedera*, *Macropanax*, *Nothopanax*, *Oreopanax* § *Lobatae*, *Panax*, *Pseudopanax* pro parte, *Stilbocarpa*.

According to Viguier, medullary resin-canals are found in the petiole in: *Acanthopanax*, *Anomopanax*, *Arthrophyllum*, *Cheirodendron*, *Cuphocarpus*, *Cussonia*, *Delarbrea*, *Didymopanax* pro parte, *Dizygotheca*, *Eremopanax*, *Gastonia*, *Heteropanax* (rachis), *Kissodendron*, *Mackinlaya*, *Macropanax*, *Meryta*, *Myodocarpus*, *Oreopanax* pro parte, *Pentapanax*, *Plerandra*, *Polyscias*, *Pseudosciadium*, *Pterotropia*, *Schefflera* pro parte, *Sciadopanax*, *Tetrapanax*, *Tetraplasandra*, *Tieghemopanax*, *Trevesia* pro parte, *Tupidanthus*. Regarding the arrangement and size of the resin-canals, see loc. cit.

The green spots occurring on the petioles and on the veins of the leaf in many species of *Meryta* are due to a local interruption of the subepidermal layer of collenchyma, which at these points is replaced by cells with green contents. The swellings found on the principal veins and on the larger secondary veins in *Meryta* and in *Strobilopanax* are mainly caused by a strong development of the inner ground tissue, which is differentiated as aqueous tissue at these points.

3. Structure of the Axis. Numerous details regarding the distribution of the **resin-canals** in the various tissues of the axis are to be found especially in Viguier's work. According to him the most important systematic point lies in the presence or absence of resin-canals in the outer collenchymatous

portion of the primary cortex and in the pith[1]. Viguier observed radially elongated secretory cavities ('poches sécrétrices') in the broad medullary rays of the wood only in *Arthrophyllum* (*A. diversifolium*); this observation requires confirmation, as it is not impossible that the structures in question are merely resin-canals, running from the cortex towards the pith.

According to Güssow, medullary **vascular bundles** are more widely distributed in the axis of the Araliaceae than was previously supposed. This author was also the first to demonstrate cortical vascular bundles in certain members of the Order. The following synopsis summarizes the results of his investigations on the distribution of the vascular bundles as seen in the transverse section of the stem.

I. Only a single ring of normally orientated vascular bundles (i.e. with the bast directed outwards and the wood pointing inwards) is found in certain species (which are named on pp. 29, 30 of the paper cited below) of: *Acanthopanax*, *Aralia*, *Astrotricha*, *Cheirodendron*, *Didymopanax*, *Fatsia*, *Gilibertia*, *Hedera*, *Horsfieldia*, *Kalopanax*, *Macropanax*, *Mackinlaya*, *Motherwellia*, *Nothopanax*, *Oligoscias*, *Panax*, *Polyscias*, *Porospermum*, *Pseudopanax*, *Pseudosciadium*, *Schefflera* and *Tetraplasandra*.

II. In addition to the normally orientated ring of vascular bundles there is a medullary ring showing inverse orientation (with bast on the inner and wood on the outer side) in: *Aralia chinensis*, L. (in this species there are also numerous small vascular bundles showing irregular arrangement of the wood and bast between the two rings), *A. dasyphylla*, Miq., *Arthrophyllum pinnatum*, Clarke and *Eremopanax otopyrenus*, Baill.

III. In addition to the normal ring of bundles there is a medullary ring, which is likewise normally orientated, in: *Arthrophyllum diversifolium*, Bl. and *Cussonia spicata*, Thunb.

IV. Besides the normal ring and a ring of medullary bundles at the periphery of the pith (which is normally orientated?, see Güssow, loc. cit., p. 30), scattered vascular bundles with irregular orientation of the wood and bast are found in the pith in: *Aralia cordata*, Thunb., *A. humilis*, Cav., *Didymopanax Morototoni*, Decne. et Planch., *D. vinosus*, March., *Kissodendron australianum*, Seem., *Pterotropia kavaiensis*, Hillebr.

V. In addition to the normal ring of vascular bundles the pith contains scattered bundles with irregular orientation of the wood and bast in: *Gastonia cutispongia*, Lam., *Meryta microcarpa*, Baill., *Plerandra Stahliana*, Warb., *Polyscias farinosa*, Harms, *Trevesia palmata*, Vis.

VI. Besides the normal ring of bundles there are cortical vascular bundles in: *Apiopetalum velutinum*, Baill., *Brassaiopsis Hainla*, Seem., *Cussonia umbellifera*, Sond., *Delarbrea collina*, Vieill., *Heteropanax fragrans*, Seem., *Myodocarpus pinnatus*, Brongn. et Gris., *Oreopanax xalapensis*, Decne. et Planch., *O. Rusbyi*, Britt., *Pentapanax angelicifolius*, Griseb., *Stilbocarpa polaris*, Decne. et Planch. (?).

VII. In addition to the normal ring of bundles both medullary and cortical vascular bundles are found in: *Aralia racemosa*, L., *Boerlagiodendron Warburgii*, Harms, *Brassaiopsis speciosa*, Decne. et Planch., *Tupidanthus calyptratus*, Hook. f. et Th.

Viguier, on the other hand, who likewise examined the structure of the axis in abundant material comprising numerous genera and species and to whom Güssow's work was unfortunately unknown, demonstrated medullary vascular bundles (constituting a single ring with inverse orientation) only in the vegetative axes of certain species of *Aralia*, which he groups together as *Euaralia* (*A. cachemirica*, *A. chinensis*, *A. cordata*,

[1] Viguier demonstrated medullary resin-canals, which exhibit diverse arrangement (viz. scattered in the pith or occupying a peripheral position and in the latter case sometimes in contact with the protoxylem of the ring of bundles) and vary in number and size, in species of the following genera: *Acanthopanax*, *Anomopanax*, *Apiopetalum*, *Aralia*, *Arthrophyllum*, *Bonnierella*, *Cheirodendron*, *Cuphocarpus*, *Cussonia*, *Didymopanax*, *Eremopanax*, *Gilibertia*, *Harmsiopsis*, *Hedera*, *Kissodendron*, *Macropanax*, *Mackinlaya*, *Meryta*, *Myodocarpus*, *Oreopanax*, *Pentapanax*, *Polyscias*, *Pseudosciadium*, *Schefflera*, *Tieghemopanax*, *Tupidanthus*.

A. dasyphylla, *A. hispida*, *A. hypoleuca*, *A. montana*, *A. nudicaulis*, *A. spinosa* and *A. urticaefolia*, but not in *A. ferox*), as well as in the axis of inflorescence of *Didymopanax Morototoni*, *Kissodendron australianum* and *Polyscias nodosa*; it remains an open question whether medullary bundles occur also in the vegetative axes of the three species last named. Viguier records cortical vascular bundles (leaf-trace bundles belonging to leaves situated higher on the axis) only in *Oreopanax*. Güssow's statements therefore still require confirmation[1].

The bundles of the normal vascular ring are no doubt always simple and collateral[2]. According to Viguier, more or less strongly developed groups of pericyclic bast-fibres are found on the outer side of the bundles in most of the species, but in some cases (e. g. in *Fatsia japonica* and species of *Echinopanax*, *Gilibertia*, *Nothopanax* and *Panax*) there is no sclerenchyma in the **pericycle**. The perimedullary tissue on the inner side of the vascular bundles is occasionally lignified or includes arcs of fibres similar to those found in the pericycle (e. g. in *Acanthopanax divaricatus*).

According to Güssow[3], the first **cork** invariably develops superficially, for the most part in the first layer of primary cortical cells, more rarely in the epidermis (*Apiopetalum velutinum*, Baill., *Delarbrea collina*, Vieill., *Macropanax undulatus*, Seem., *Polyscias xanthoxyloides*, Harms). The cells of the cork often have thin walls: in *Aralia humilis*, Cav. some of them exhibit a palisade-like elongation; in other cases the cork-cells are thickened on the tangential walls (species of *Cussonia*, *Giliberlia*, *Oreopanax*, *Schefflera*) or on all sides (*Pseudopanax laetevirens*, Benth. et Hook.); thick-walled sclereids are found in the cork in *Oreopanax xalapensis*, Decne. et Planch. and *Polyscias xanthoxyloides*, Harms. Certain species have a more or less closed ring of stone-cells belonging to the phelloderm. Stone-cells likewise occasionally occur in the **primary cortex**, but the characteristic mechanical tissue of the latter is collenchyma, which is rarely absent and for the most part forms a completely closed ring, 5–6 layers of cells in thickness, in the outer portion of the primary cortex.

The following additional details regarding the structure of the **wood**[4] are based on Güssow's statements[3]. The medullary rays vary from one to seven cells in breadth. Spiral thickening of the walls of the vessels has been demonstrated in *Aralia humilis*, Cav., *Astrotricha floccosa*, DC., *A. ledifolia*, DC. and *Nothopanax diversifolius*, Harms; the perforations in the vessels show a transition to the scalariform type also in species of *Horsfieldia*, *Trevesia* and *Tupidanthus*. The wood-parenchyma is mostly restricted to the neighbourhood of the vessels, although it is occasionally developed in greater abundance, e. g. especially in *Nothopanax diversifolius*. Tracheids are absent. Güssow invariably found simple pits on the wood-prosenchyma. The same authority observed septation of the wood-prosenchyma together with storage of starch,

[1] Güssow gives no details as to the exact nature of the material employed in his investigations of the stem. From what has been mentioned above it is in no way improbable, that Güssow's statements in part at least refer to the axis of inflorescence and not to the vegetative axis; nor is it quite impossible, that Güssow occasionally investigated petioles in place of axes.

[2] According to Güssow, bicollateral bundles are not uncommon in the Araliaceae, even in the normal vascular ring. Among the species enumerated by Güssow (loc. cit., pp. 34, 35) in this relation *Panax quinquefolius*, L. (*Aralia quinquefolius*) was the only one at my disposal. In this species the outer soft bast extends round the body of the wood in the shape of a horseshoe, but the bundles are not typically bicollateral.

[3] Regarding the material on which Güssow's investigation of the axis was undertaken, see footnote 1, above.

[4] Viguier records a 'bois homoxylé' devoid of secondary vessels in *Nothopanax anomalus* and *N. microphyllus*; thick axes were, however, not examined!

also in species of ***Arthrophyllum, Didymopanax, Eremopanax, Gastonia, Gilibertia, Kalopanax, Macropanax, Nothopanax, Oligoscias, Oreopanax, Pseudopanax, Schefflera, Tupidanthus***, &c.

The **pith** consists of cells with thin or thickened walls; starch is occasionally stored in the peripheral cells.

Literature: Möbius, Mechan. Scheiden der Sekretbeh., Ber. deutsch. bot. Gesellsch., 1884, Generalversammlungsheft, p. xxvi.—C. de Candolle, Infloresc. épiphylles, Mém. Soc. de phys. et d'hist. nat. Genève, 1890, vol. suppl., sep. copy, p. 5 et seq.—Barber, Corky excresc., Ann. of Bot., vi, 1892, p. 166.—Went, Haft- u. Nährwurzeln, Ann. Jardin Buitenzorg, xii, 1895, pp. 55–6.—[Zancla, Aculei, Contribuz. Istit. bot. Palermo, ii. 1897, p. 1 et seq.]—Baranetzky, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xii, 1900, pp. 304–7.—Güssow, Beitr. z. vergl. Anat. d. Araliac., Diss., Breslau, 1900, 68 pp., 1 Tab.—Petersen, Vedanatomi, 1901, p. 70.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1901, pp. 25–6 (*Hedera*).—[Chrysler, Central cylinder of Aral. and Liliaceae, Bot. Gazette, 1904, pp. 161–85.]—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, especially pp. 179–81.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 150, 151 (*Arthrophyllum*).—Piccioli, Legnami, Bull. Siena, 1906, p. 132.—Viguier, Rech. anat. sur la classification des Araliac., Ann. sc. nat., sér. 9, t. iv, 1906, pp. 1–207.—Holtermann, Einfluss des Klimas, etc., 1907, p. 135 (*Heptapleurum*).—[For further literature, see p. 1169.]

CORNACEAE (pp. 432–439).

1. Review of the Anatomical Features. On the basis of Wangerin's work we may add that simple perforations occur in the vessels in ***Kaliphora*** also, crystal-sand also in ***Kaliphora*** and ***Melanophylla***, and stellate hairs with a varying number of rays (a type of hair new to the Cornaceae) in ***Alangium costatum***, Wangerin.

2. Structure of the Leaf. The earlier inexact statements on the occurrence of papillose **epidermal cells** (on p. 433) may be replaced by the following details quoted from Köhne's and Sertorius' observations.

Papillose development of the upper epidermis is found in: *Garrya elliptica*, Dougl., *G. flavescens*, Wats., *G. laurifolia*, Benth., *G. Lindheimeri*, Torr., *G. ovata*, Benth., *G. Wrightii*, Torr. (the species last named has solid peg-shaped papillae), *Marlea begoniaefolia*, Roxb., *M. macrophylla*, S. et Z., *M. platanifolia*, S. et Z. and *Cornus canadensis*, L. In *Garrya* the outer walls of the lower epidermal cells, like those of the upper epidermis, are more or less distinctly papillose, and this is even the case in species which show no tendency to form papillae on the upper side. The lower epidermal cells are slightly papillose also in *Aucuba japonica*, Thunb., *A. himalaica*, Hook. f., *Nyssa capitata*, Walt., *N. uniflora*, Wang., *Torricellia tiliaefolia*, DC., *Cornus alternifolia*, L. f., *C. florida*, L. and *C. stolonifera*, Michx. In other species of *Cornus* the lower side of the leaf bears distinct papillae, which are generally provided with a corona and stand in connexion with one another by means of reticulately arranged cuticular ridges; these species are: *C. alba*, L., *C. asperifolia*, Michx., *C. brachypoda*, C. A. Mey., *C. californica*, C. A. Mey., *C. candidissima*, Mill., *C. capitata*, Wall., *C. circinata*, L'Hérit., *C. disciflora*, DC., *C. Hessei*, Köhne, *C. ignorata*, Koch, *C. macrophylla*, Wall., *C. oblonga*, Wall., *C. paniculata*, L'Hérit., *C. pubescens*, Nutt., *C. Purpusi*, Köhne, *C. sibirica*, Loddig., and *C. tatarica*, Mill.

In ***Mastixia Cambodiana***, Pierre the **petiole** is supplied by three vascular bundles which ultimately form a central cylinder (Pierre).

3. Structure of the Axis. According to Wangerin, the cork also arises in the subepidermal layer of cells in ***Kaliphora*** and ***Melanophylla***. The same author states that the vessels of the secondary wood have simple perforations in ***Kaliphora***, and scalariform perforations in ***Melanophylla***, as well as in ***Alangium (Marlea) Mezianum***, Wangerin and ***A. costatum***, Wangerin.

According to Pierre, ***Mastixia Cambodiana***, Pierre, like the other species of ***Mastixia***, is distinguished by having medullary secretory canals and by the stratification of the phloem into hard and soft bast.

Literature: Pierre, Flore forest. de la Cochinchine, xvii, 1892.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Köhne, Papill. u. obers. Spaltöffn., Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 59.—Petersen, Vedanatomi, 1901, p. 68.—Bouygues, Pétiole, Thèse, Paris, 1902, p. 13.—Gauchery, Hybridité, Assoc. franç. Congrès Ajaccio, 1901, ii, ed. 1902, pp. 403-8 (*Garrya elliptica* × *Fadyena*).—Gerhard, Blattanat. von Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 21-2 (*Curtisia*).—Theorin, Växttrichom., Arkiv för Bot., i, 1903, p. 159.—Süssenguth, Behaarungsverh. d. Würzburger Muschelkalkpfl., Diss., Würzburg, 1904, p. 35.—Piccioli, Legnami, Bull. Siena, 1906, p. 162.—Wangerin, Umgrenz. u. Gliederung d. Fam. d. Cornac., Diss., Halle, 1906, 92 pp., especially pp. 50, 65, 72, 79 and 82; sep. copy from Engler, Bot. Jahrb., xxxviii.

CAPRIFOLIACEAE (pp. 439-444).

1. Review of the Anatomical Features. The mention of *Adoxa* among the exceptions to the 'occurrence of glandular hairs' must be cancelled.

2. Structure of the Leaf. The mesophyll also includes arm-palisade parenchyma in *Adoxa Moschatellina* (here composed of low cells, Lagerberg) and *Viburnum pauciflorum* (Schwartz-Clements). Papillose differentiation of the **epidermis** is found on both sides of the leaf in *Lonicera syringantha*, Maxim. and *L. tomentella*, Hook. f. et Th., on the upper side only in *L. arborea* Boiss. and *L. Standishi*, Carr., and on the lower side only in *L. floribunda*, Boiss. et Buhse, *L. rupicola*, Hook. f. et Th. and *L. Zabeli*, Rheder; in *Symphoricarpus Heyeri*, Dipp. and *S. occidentalis*, Hook., thick conical papillae occur in the neighbourhood of the stomata, while in *S. orbiculatus*, Moench, there are weakly developed papillae on the lower side of the leaf (Köhne). The **stomata**,—and more emphasis can be laid on this point than formerly,—are in no case exclusively provided with subsidiary cells of the Rubiaceous type.

The club-shaped external **glands** found on the leaves of *Adoxa* are provided with a short stalk consisting of 2 or 3 cells and a bicellular head divided by a vertical wall (Lagerberg). Novak had previously met with external glands, with more numerous cells, at the base of the petals.

3. Structure of the Axis. The vascular system in the rhizome of *Adoxa Moschatellina* consists of two collateral arc-shaped vascular bundles, which are enveloped by a narrow parenchymatous pericycle, an endodermis provided with Caspary's dots and a cortex rich in starch. It is noteworthy that even the pitted tracheae are devoid of perforations, so that they are merely elongated tracheids.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 72 et seq.—Kassner, Mark, Diss., Breslau, 1884, pp. 15-16.—Nancke, Dikotyle Holzpfl., Diss., Konigsberg, 1886, p. 31.—Aufrecht, Extraflorale Nektar., Diss., Zürich, 1892, p. 25 et seq. (*Viburnum Opulus*).—Hartwich, Falsche Senegawurzel, Archiv d. Pharm., 233, 1895, pp. 121-3 and Tab.—[Sayre, *Viburnum*, Americ. Journ. Pharm., 1895, p. 465.]—[Möller, Attichwurzel, Pharm. Post, 1895, p. 113 et seq.]—[Dermiston, Comp. struct. of the barks of cert. Americ. *Viburnums*, Pharm. Archives, i, 1898.]—Köhne, Papill. u. obers. Spaltöffn., Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 60.—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 43, 44.—Petersen, Vedanatomi, 1901, pp. 87-93.—Clauditz, Blattanat. kanar. Gew., Diss., Basel, 1902, pp. 36, 37 (*Viburnum*).—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 9.—[Novak, *Adoxa Moschatellina*, in Theodora Novaka stati nyleraná, Prag, 1902, pp. 148-60 (Bohemian; abstr. in Bot. Centralbl., xc, p. 546).]—Thouvenin, Glandes pét. du *Viburnum Opulus*, Revue gén. de bot., xv, 1903, pp. 97-103.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 129 and 133.—Lagerberg, *Adoxa Moschatellina*, Arkiv för Bot., iii, 1904, sep. copy, 28 pp. (Swedish).—Paoli, Eterofillia, Nuovo Giorn. bot. Ital., xi, 1904, p. 226.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 35.—Theorin, Växttrichom., Arkiv för Bot., iii, n. 5, 1904, p. 6.—Guttenberg, Lichtsinnesorg., Ber. deutsch. bot. Gesellsch., 1905, p. 265 et seq. and Tab. x, xi.—Haberlandt, Lichtsinnesorg., 1905, p. 69 and Tab. i.—Schwartz-Clements, Relation of leaf-structure to phys. fact., Transact. Americ. Microscop. Soc., 1905, p. 63, pl. vii, 5 a.—Dauphiné, Rhizomes, Ann. sc. nat., sér. 9, t. iii, 1906, p. 359 (*Adoxa*).—Piccioli, Legnami, Bull. Siena, 1906, pp. 153 and 156.—[For further literature, see p. 1169.]

RUBIACEAE (pp. 444–454).

2. Structure of the Leaf[1]. Centric structure with two layers of palisade-cells on both sides of the leaf occurs for instance in *Asperula cynanchica* (Netolitzky), while in *Borreria verticillata* the mesophyll is homogeneous (Saint-Just). Numerous papillae are found on the upper epidermis above the larger veins in *Galium cruciatum*, Scop. and *G. pedemontanum*, All. (Netolitzky); hypoderm is developed on the upper side of the leaf in *Craterispermum microdon* (Fabricius), as well as in *Cinchona caloptera*, Miq., *Hydnophytum formicarum*, Jack, *Myrmecodia echinata*, Gaud., and *Scyphiphora caryophyllacea*, Gaertn. (Areschoug) and in *Leucocodon reticulatum* (Holtermann). Sclerenchymatous fibres running freely in the mesophyll are mentioned by Fabricius as occurring in a plant described as '*Pyrostria* sp. n.' and one incorrectly determined as *Gardenia Annae*[2], while Fröhner records them in *Coffea brachyphylla*, Radlk. and *C. Zanguebariae*, Lour. For the structure of the rolled leaves of *Anthospermum* and *Nenax*, see Knoblauch, loc. cit.

To the section on the **hairy covering** (p. 447) we may first add that the bent unicellular hairs, found in the Stellatae, are not always typical hooked hairs, *i.e.* curved like the horn of a chamois, but are sometimes merely hamose or sickle-shaped (Netolitzky). Glandular shaggy hairs of somewhat simpler structure than those depicted in Fig. 101 A have been observed by Mardner in *Galium antarcticum*, Hook. f., where they lie at the base of the four leaves of the whorl, and by Holtermann in *Hedyotis verticillaris*, where they are found at the bases of the leaves, which are here united to form a small ochrea; these glands therefore occur also on the lamina of the leaf. Regarding the glandular shaggy hairs, see also Mastrostefano and Mirabella, ll. cc.

Elongated **secretory sacs** having wide lumina, filled with bright brown contents, are found also in the veins of the leaf in *Pyrostria* (Fabricius), and secretory sacs, like those present in the cortex of *Cinchona*, occur also in the cortex of *Corynanthe Johimbe*, K. Sch. (Gilg); epidermal secretory sacs are found at the apex of the leaf in *Galium hirsutum*, Ruiz et Pav. (Weberbauer); the well-known elongated secretory sacs of the *Cinchonas* are present also in the pith (Meyer). Saint-Just's statement as to the occurrence of 'canaux sécréteurs' in *Manettia luteo-rubra* is certainly incorrect; the same author records secretory cells in species of *Borreria*, *Coprosma*, *Ernodea*, *Hoffmannia*, *Morinda*, *Palicourea*, *Spermacoce* and *Vangueria*, but his statements on this subject are inexact and hence scarcely reliable, so that we can do no more than briefly mention them (see also under 'secretory cells filled with brown contents' on p. 448). Netolitzky associates with the secretory organs peculiar groups of strongly enlarged epidermal cells, which have greenish, strongly refractive contents in the form of small drops, and occur on the lower side of the leaf-tip in certain species of *Galium* (*G. boreale*, L., *G. cruciatum*, Scop., *G. pedemontanum*, All., *G. rotundifolium*, L., *G. rubioides*, L.). We may likewise include here the peculiar crypts found by Saint-Just on the lower side of the leaf in *Coprosma lucida*, but not very accurately described by him; these structures, which occur at the base of the secondary veins, are lined with a two-layered

[1] Our knowledge of the structure of the leaf in the Rubiaceae is still very insufficient. Netolitzky has recently investigated the anatomy of the leaves of the endemic Stellatae. The statements in Saint-Just's paper, which also deals with this Order, are unfortunately very inexact and in part incorrect: moreover some of his plants are certainly incorrectly determined, as may be concluded from the mode of deposition of oxalate of lime.

[2] In view of the presence of the characteristic crystal-hairs this plant must be one of the Guettardeae. The 'secretory cells with dark granular contents' observed by Fabricius are doubtless sacs containing crystal-sand.

epithelium of elongated palisade-like cells, and open towards the outside by means of a narrow aperture, covered in by trichomes.

To the synopsis of the diverse crystalline forms in which **oxalate of lime** is deposited in the genera of the Rubiaceae (pp. 450, 451) we may add: Under I. Crystal-sand: after *Condaminea*: *Corynanthe*; further, under 'together with the crystal-sand, clustered crystals': *Cinchona*. Under II. Raphides: after *Cruckshanksia* in brackets: *C. Montiana*, Gay; further at the points determined by the alphabetical sequence: *Coprosma*, *Hydnophytum*, *Myrmecodia* and *Oreopolus* (*Cruckshanksia glacialis*, Poepp.). Under III. Clustered crystals: *Pyrostria*. We may also note that in some cases there are no raphides in the raphide-sacs, so that the latter are accompanied by mucilage-sacs (e.g. commonly in the leaf of *Asperula odorata*, L.).

Netolitzky met with sphaerocrystalline masses having the appearance of hesperidin-crystals in alcohol-material and glycerine-preparations of many of the Stellatae (e.g. *Galium lucidum*, All. and *G. palustre*, L.). In the bast of some kinds of *Cinchona*-bark, which are rich in alkaloid, the latter occasionally crystallizes out.

3. STRUCTURE OF THE AXIS. According to Saint-Just, the **cork** develops superficially (viz. in the subepidermal layer or in the second layer of primary cortical cells) in the species of *Chione*, *Faramea*, *Gardenia*, *Genipa*, *Guettarda*, *Ixora*, *Laugueria*, *Pentas*, *Randia*, *Rondeletia*, *Rudgea*, *Strumpfia* examined by him, while it arises in the pericycle in the species of *Coprosma*, *Leptodermis* and *Paederia*. In the species of *Chimarrhis*, *Faramea*, *Guettarda*, *Hamelia*, *Hyptianthera*, *Ixora*, *Morinda*, *Mussaenda*, *Paederia*, *Pavetta*, *Plectronia*, *Posoqueria*, *Psathura*, *Psychotria*, *Urophyllum* and *Vangueria* investigated by Pitard the **pericycle** contains isolated bundles of bast-fibres; the latter are wanting, however, in the officinal *Cinchona*-bark. As regards the structure of the **wood** we may mention that *Craterispermum microdon*, Bak., like the other Vanguerieae, has simple perforations in the vessels and wood-prosenchyma bearing bordered pits (Ursprung).

According to Goldstein, cortical vascular bundles showing concentric structure are found in *Sickingia*. Baranetzky's statement as to the occurrence of bicollateral vascular bundles in a member of this Order (*Plectronia ventosa*) is incorrect; the plant examined by him is not *Plectronia ventosa*, nor even one of the Rubiaceae (Solereder).

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 142 et seq.—Goldstein, Rinde von *Arariba*, etc., Diss., Erlangen, 1892, 30 pp., 2 Tab.—Brandt, Wenig bek. Rinden, Diss., Dorpat, 1894, p. 52 et seq.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Jonsson, Anat. Bau d. Bl., Acta Univ. Lund., xxxii, 2, 1896.—Knoblauch, Ökolog. Anat., Habilitat.-Schr., Tübingen, 1896, p. 9 et seq.—Elfstrand, Heilpfl., Ber. deutsch. pharm. Gesellsch., 1897, p. 291 (*Palicourea*).—[Mastrostefano, Stellate, Bollett. Soc. Natural. Napoli, 1897, p. 75; abstr. in Just, 1898, ii, p. 270.]—[Mirabella, Colleteri, Contrib. Ist. bot. Palermo, ii, 1897, p. 15 et seq.; abstr. in Just, 1897, i, p. 513.]—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 63.—Boergesen og Paulsen, Veget. dansk-vestind. Öer, Bot. Tidsskrift, xxii, 1898–9, pp. 96, 97 (*Randia aculeata*, L.).—Fröhner, *Coffea*, in Engler, Bot. Jahrb., xxv, 1898, p. 236 et seq.—Tichomirow, Mechan. Elemente bei *Cinchona*, Bot. Centralbl., 1899, 1, p. 60.—Baranetzky, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xii, 1900, pp. 292–4.—Charpentier, Ét. anat. et microchim. d. quinquinas de cult., Thèse, Paris, 1900, 50 pp., 2 pl.—Gamper, Angosturarinden, Diss., Zürich, 1900, pp. 62, 63.—G. Meyer, Anat. d. auf Java kult. Cinchonen, Zeitschr. f. Naturw., lxxii, 1900, pp. 409–41; see also Hartwich and G. Meyer, in Archiv d. Pharm., 238, 1900, p. 253.—Ursprung, Anat. u. Jahresringbild. trop. Holzarten, Diss., Basel, 1900, pp. 23–5 (*Craterispermum microdon*, Bak.).—Gilg and Schumann, Johimberinde, Berliner Notizbl., iii, no. 25, 1901, pp. 92–4; see also Gilg, in Ber. deutsch. Pharm. Gesellsch., 1901, p. 212.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 91.—Areschoug, Mangrovepfl., Bibl. bot., Heft 56, 1902, pp. 52–5 and Tab. v, vi.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 565 et seq. (*Mussaendopsis*, *Sarcocephalus*).—Clauditz, Blattanat. kanar. Gew., Diss., Basel, 1902, pp. 36, 37 (*Phyllis*).—Fabricius, Laubbl.-Anat., Beih. z. Bot. Centralbl., xii, 1902, pp. 314–17.—Gerhard, Blattanat. v. Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 22, 23 (*Plectronia*).—Knothe, Unbenetzb. Bl., Diss., Heidelberg, 1902, p. 9.—Mardner, Phan.-Vegetat. d. Kerguelen, Diss., Basel, 1902, pp. 27, 28 (*Galium*).—[Armari, Piante della reg. medit., Ann. di bot., 1, 1903, p. 17 et

seq. (*Putoria*).]—Gorris et Reimers, *Cinchona robusta*, Bull. Soc. pharmacol., 1903, pp. 384–6; also in Perrot, Travaux, II.—[Greensill, Struct. of leaf of cert. spec. of *Coprosma*, Transact. and Proceed. New Zealand Inst., xxxv, 1903, pp. 342–55 and pl. xli–xliv.]—Solereder, Berichtig., Bull. Herbier Boissier, 2° sér., 1903, pp. 324, 325.—Achner, Falsche Chinarinden, Diss., Bern, 1904, 109 pp.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 119–21.—Saint-Just, Rech. anat. sur l'appareil vég. aérien des Rubiac., Thèse, Paris, 1904, 70 pp., 2 pl.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 36.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 50, 51 (*Spermacoce*), pp. 73, 74 (*Dentella*), pp. 86, 87 and Tab. xiii (*Cinchona*), pp. 90, 91 (*Coffea*), p. 108 (*Myrmecodia*), and pp. 144–6 and Tab. vi–viii (*Hydnophytum*).—Netolitzky, Dikotylenbl., Vienna, 1905, pp. 9–33.—Russell, Principes actifs de la Garance, Revue gén. de bot., 1905, p. 254 et seq.—Theorin, Vaxtrichom., Arkiv for Bot., iv, n. 18, 1905, p. 17.—Weberbauer, Vegetat. d. Hochanden Perus, in Engler, Bot. Jahrb., xxxvii, 1905, p. 60 et seq.—Holtermann, Einfluss des Klimas etc., 1907, pp. 59, 83, 130 and 135 (*Scyphiphora*, *Spermacoce*, *Hedyotis*, *Leucocodon*).—[For further literature, see p. 1172.]

VALERIANEAE (pp. 454, 455).

The following details may be added to the account given in the earlier part of this book; they are mainly extracted from Vidal's work. In the species of *Patrinia*, *Centranthus*, *Valeriana*, *Fedia* and *Valerianella* examined by Vidal the structure of the **leaf** is again mostly bifacial, although it is centric in *Valeriana saliunca* and almost homogeneous in *V. dioica*. Twin stomata are frequently met with on both surfaces of the leaf in *Valerianella*; water-pores are found also in *Valeriana Phu*. The lateral margins of the **epidermal cells** are either straight or undulated. Vidal observed glandular hairs in all the species; the multicellular heads of these hairs are either elongated or spherical and are for the most part divided both by horizontal and vertical walls, rarely (*Valeriana tripteris*) by vertical walls only. As regards the **fibrovascular system** of the leaf we may note that there is no mechanical tissue in the veins apart from collenchyma. The leaf is supplied by three vascular bundles, which in the upper portion of the petiole pass over into a widely open arc composed of five bundles. In *Valeriana officinalis*, according to Bouygues, the petiole contains several concentric vascular bundles (steles), some of which are not quite completely differentiated; each of these bundles is provided with a pith and an enveloping endodermis. **Oxalate of lime** has been found in the vegetative organs [1] only in *Patrinia*, where it was first observed by Chatin; it occurs in the form of clustered crystals, which are present in the root, stem, and leaf. On the other hand, structures of unknown chemical composition, but resembling sphaerites, appear in the leaves and other organs of many Valerianeae (e.g. *Valeriana saliunca*) after treatment with alcohol; these bodies recall the sphaerocrystals of inulin. Oil-cells, first observed by Zacharias in the root of *Valeriana* and distinguished from the neighbouring cells by their contents and their suberized wall, are, to judge by Vidal's statements, present in the root also in other species of *Valeriana*, as well as in *Patrinia*, *Centranthus*, *Fedia* and *Valerianella*; they are situated either in the second cell-layer of the primary cortex beneath the suberized outermost layer, or are found in a slightly deeper layer. According to Vidal, however, the chief production of oil in the roots takes place in the cork, which explains the large amount of oil found in the older roots.

For details as to the structure of the **stem**, rhizome, and root, see Vidal, loc. cit.; it will suffice to mention the following facts here. Apart from the superficial development of the cork in the roots and rhizomes of *Valeriana officinalis* and *V. Phu*, the cork invariably arises in the pericycle in both organs. There are no mechanical elements in the pericycle. The inner portion of the

[1] According to Vidal, the pericarp of *Centranthus*, *Valeriana*, *Fedia* and *Valerianella* contains oxalate of lime in the form of solitary crystals, although there is no oxalate of lime in the vegetative organs.

pith of the stem consists of unlignified cells and subsequently becomes fistular. In the roots of *Valeriana officinalis* and *V. Phu* the cells of the endodermis, which are provided with Caspary's dots, are persistent in consequence of the superficial development of the cork and exhibit secondary division-walls in the same way as in certain Gentianeae.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 146.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Biermann, Ölzellen, Diss., Bern, 1898, pp. 30-5.—Thomas, Feuilles sout., Thèse, Paris, 1900.—Dye, Unterird. Org. von *Valeriana* etc., Diss., Bern, 1901, pp. 6–35 and Tab. 1.—Bouygues, Pétiole, These, Paris, 1902, p. 71.—L. Vidal, Anat. des Valérian., Ann. de l'Univ. de Grenoble, xv, 1903, sep. copy, especially pp. 6–31; see also the author's abstract in Bot. Centralbl., xcv, p. 146.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xii, 1904, p. 136.—Weberbauer, Vegetat. d. Hochanden Perus. in Engler, Bot. Jahrb., xxxvii, 1905, p. 60 et seq.

DIPSACEAE (pp. 455, 456).

Szabo's recent investigation of the anatomy of the genus *Knautia* has afforded the following results. External glands with a short stalk and a head composed of four or more cells occur also in this genus. *K. orientalis*, unlike other species of the genus, has scalariform perforations in the vessels. The cork in *K. longifolia* (rhizome) develops in the pericycle.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 145 et seq.—Mittmann, Pflanzenstacheln, Verh. bot. Ver. Brandenburg, 1889, p. 67 and Tab. i.—Lothelier, Épines, Thèse, Paris, 1893, p. 39 and pl. iii.—[Cacace, Contrib. stud. d. Dipsacee, Ric. istol., R. Orto bot. Napoli, 1898, 12 pp.]—Rostock, Drusenb. von *Dipsacus silvestris*, Bot. Zeit., 1904, Abt. 1, pp. 11-20.—Sussenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 36.—Szabo, Monogr. d. Gatt. *Knautia*, in Engler, Bot. Jahrb., xxxvi, 1905, pp. 401–8.

CALYCEREAE (p. 456).

According to Reiche, 'the absence of special bast-strands in the cortical parenchyma' is a feature common to all the Calycereae. *Boopis australis*, Decne., *B. gracilis*, Phil., *B. multicaulis*, Phil. and *B. graminea*, Phil. possess a lignified strengthening ring, in which the vascular bundles are embedded. The fleshy stems found in various species of *Nastanthus* are due to abundant development of the medullary and cortical parenchyma.

Literature: Reiche, Calycereen, in Engler, Bot. Jahrb., xxix, 1900, p. 110.

COMPOSITAE (pp. 456–469).

1. Review of the Anatomical Features. Secretory cavities also occur in the leaves of *Trilisa* and species of *Athanasia*; in certain members of the Order, moreover, they take the place of the secretory canals in the subterranean organs. Secretory sacs, which are often much elongated and have milky or resinous contents, are found in species of *Gazania* (Tribe Arctotideae, in this case together with transitions to laticiferous vessels), and *Vernonia* (Tribe Vernonieae), as well as in members of the Tribe Cynaroideae (*Alfredia, Arctium, Atractylis, Berardia, Carduus, Carlina, Chardinia, Cirsium, Cousinia, Galactites, Jurinea, Lappa, Onopordon, Silybum, Staehelina, Warionia*; in *Atractylis* and *Carlina*, together with transitions to laticiferous vessels). Beyond the limits of the Cichoriaceae and apart from the genus *Gundelia* (Tribe Arctotideae), which was already referred to in the earlier part of this work, laticiferous vessels occur in *Gazania*, which belongs to the same Tribe as *Gundelia*, and in *Carlina* and *Atractylis* (Tribe Cynaroideae, Subtribe Carlineae). Unicellular trichomes appear to be wanting in the hairy covering of the Compositae. Recent investigations have shown that multicellular clothing hairs with a

two-armed or stellate terminal cell occur in many additional genera. Vesicular integumental glands, showing the same type of structure as those found in the Labiatae, are present in *Centauropsis*, while extrafloral nectaries occur in *Helianthus*. To the list of special or anomalous structural features presented by the axis we may add : the arrangement of the vascular bundles in indistinct rings, as in the stem of a Monocotyledon, in species of *Scorzonera* and *Centaurea*, as well as in species of *Cynara* ; and the occurrence of medullary or cortical vascular bundles in species in which these anomalies were not previously known. Anomalous structure has recently been demonstrated in the fleshy adventitious roots of *Thrincia tuberosa*, DC. (transformation of the primary xylem-groups of the vascular system into steles) and in the tap-root of *Atractylis gummifera*, L. (appearance of concentric secondary meristems in the wood of the root, and development of rings of vascular bundles, which alternately show normal and inverse orientation).

2. SPECIAL ANATOMICAL DIAGNOSIS. A very important feature of the **hairy covering** (see p. 457) lies in the fact that unicellular hairs really appear to be absent in the Compositae, just as in the Papilionaceae. G. Fischer's statements as to the presence of unicellular hairs in certain species of genera belonging to the Vernonieae and Eupatorieae (*Agrianthus, Bolanosa, Hoplophyllum, Piptolepis, Vernonia*) have proved to be incorrect upon reinvestigation, the basal cells of the hairs having been overlooked. Recent observations have shown that simple uniseriate clothing hairs with a long terminal cell (flagellum-trichomes) are very widely distributed. They occur in many genera of the Vernonieae and Eupatorieae, e.g. in species of *Adenostyles, Bothriocline, Brickellia, Centauropsis, Elephantopus, Liatris, Rolandra, Soaresia, Telmatophila, Vernonia*, &c. (G. Fischer), as well as in species of *Anacyclus, Athanasia, Culcitium, Hieracium, Lucilia* and *Senecio*. In *Balanosa Coulteri*, Gray and *Stilpnopappus speciosus*, Bak., the terminal cells of these flagellum-hairs exhibit a nodose thickening at their base (G. Fischer), while in *Cirsium horridum*, M. Bieb., the basal portion of the terminal cell is enlarged in a campanulate manner ; in certain species of *Senecio* (Wagner) and *Anacyclus* (Feuilloux) the terminal cells are placed at an angle to the stalk, in the same way as in the hairs of *Brocchia cinerea* (see p. 458). Uniseriate hairs with a two-armed terminal cell, which in other respects shows varied structure, have been demonstrated also in certain species of *Albertinia, Centauropsis, Eremanthus, Lychnophora, Oliganthes, Piptolepis, Pithecoseris, Vanillosmopsis*, and *Vernonia* by G. Fischer, and in certain species of *Anacyclus* and *Athanasia* by Feuilloux ; I have found them also in *Senecio incanus*, L. and *S. uniflorus*, All., which is not in agreement with P. Wagner, who speaks of peltate hairs as occurring in these species. Uniseriate hairs with a stellate terminal cell, which varies in the thickness of its walls and in the number of rays, occur also in species of *Blanchetia, Haplostephium, Lycnophora, Piptocarpha* and *Piptolepis* (according to G. Fischer), in species of *Artemisia* and *Athanasia* (according to Feuilloux), in species of *Vernonia* (according to Grimm), and apparently also in the genera *Baccharis* and *Santolinum* (according to A. Weiss) ; uniseriate hairs with a candelabra-like terminal cell are found in *Scorzonera hispanica*, L. (Theorin). These different forms of hair in which the terminal cells are simple, two-armed or stellate are as a rule only characteristic of the species and not of the genus. Thus, according to Feuilloux, all three types of hair are found within the limits of the genera *Artemisia* and *Athanasia* (hairs with a simple terminal cell, for example, in *Artemisia ramosa*, Sm. and '*Athanasia parviflora*, L.' ; hairs with a two-armed terminal cell in *Artemisia Absinthium*, L. and *Athanasia pinnata*, L. ; and hairs with a stellate end-cell in *Artemisia glauca*, Pall. and *Athanasia pubescens*, L.), while trichomes with a simple and with a two-armed terminal cell both occur in the genus *Anacyclus*

(hairs with a simple end-cell, for example, in *A. clavatus*, Pers., and two-armed hairs in *A. pedunculatus*, Pers.); further, according to G. Fischer, trichomes with a two-armed and with a stellate terminal cell are found side by side in *Lychnophora salicifolia*, Mart. and *Piptolepis ericoides*, Schultz Bip., and hairs with simple and two-armed end-cells side by side in *Centauropsis lanuginosa*, Boj. Clothing hairs of the shaggy type have recently been observed by G. Fischer also in *Hofmeisteria pluriseta*, Gray (here provided with a papillose surface), *Piptocarpha lucida*, Bak. (likewise papillose) and *Vernonia inulaefolia*, Steud., as well as by Noè von Archenegg in *Cirsium horridum*, M. Bieb., and other species of *Cirsium* belonging to the section *Epitrachys*. The shaggy hairs found in the species of *Cirsium* occur on the upper side of the leaf and are composed of pitted sclerenchymatous fibres, which penetrate into the mesophyll in the form of a bundle and thus constitute a base to the shaggy hair, similar to that found in many Melastomaceae; ultimately the bundle of fibres becomes apposed to the vascular bundle of a vein. Both the epidermis and the subepidermal layer of cells are concerned in the formation of these shaggy hairs. A transition to the shaggy hairs is represented, among other forms of trichomes, by the clothing hairs of *Artemisia argentea*, L'Hérit., which are provided with a narrow elongated terminal cell and are seated on a high pedestal, the lower tiers of which are formed of several cells. Characteristic shaggy hairs, showing a reduced type of structure and similar to those found in *Spilanthes oleracea* (Fig. 103, *N* and p. 460), appear to be rather widely distributed on the floral parts (ovary) in the Compositae; they consist of two basal cells, which are prolonged upwards to an unequal extent, and two long hair-cells, which are joined together lengthways along one side, but diverge apically so as to resemble a swallow's tail; hairs of this kind are found, for example, also in *Atractylis gummifera*, L. and *Carlina acaulis*, L. (Kerckhoff). With these hairs we may class the peculiar trichomes, observed by Schinz on the same organs of the plant in *Sphaeranthus epigaeus*, Schinz; their distinctive feature lies in the fact that the two terminal cells, which have rounded ends, are spirally wound around one another (with two turns to the spiral).

We will next consider the **glandular hairs**. As far as can be gathered from G. Fischer's statements, which are unfortunately in part incomplete and not clearly presented, the characteristic biseriate vesicular integumental glands were observed by him in certain Vernonieae and Eupatorieae; Tunmann also met with them in *Achillea*. If we imagine the appearance of vertical and oblique division-walls in these biseriate glands we obtain the shortly stalked external glands found in *Haplopappus* and *Gochnatia*; in these glands, which were not noticed in the previous review, the cells are arranged in the three directions of space (Volkens). Multicellular glandular hairs with a unicellular head are found in species of *Brickellia*, *Kuhnia*, and *Trichocoronis* (according to G. Fischer), in *Senecio Boissieri*, DC. (according to P. Wagner), and in *Centaurea* (according to Briquet); almost sessile glands with two short basal cells and a secretory head-cell are figured by Feuilloux in *Athanasia leucoclada* and glandular hairs with a uni- or biseriate stalk and a spherical head, divided by horizontal and vertical walls into 4–8 cells, by G. Fischer in *Hofmeisteria pluriseta*, Gray; vesicular integumental glands having a short stalk and resembling the glands of the Labiatae, occur in *Centauropsis lanuginosa*, Boj. The extrafloral nectaries, observed by Delpino in *Helianthus giganteus* and *H. tuberosus*, have not yet been closely examined; they are situated on the uppermost leaves (on the lower side near the base of the leaf) in the neighbourhood of the floral region.

Our previous knowledge regarding the internal **secretory organs** of the Compositae (see p. 460 et seq.) has been very considerably extended, especially by Col's recent investigations.

Schizogenous **secretory canals** are found in certain members of all the thirteen Tribes included in Bentham and Hooker's system, although they are of rare occurrence in the Cichoriaceae. In this Tribe they are to some extent replaced by laticiferous vessels, just as in certain Cynaroideae their place is taken by secretory sacs with milky or resinous contents. The characteristic position in which they occur is in the root; this statement must not, however, be taken to imply that they are not very frequently found traversing the subaerial portions of the plant as well (i. e. axis and leaf). No case is known among the Compositae of the occurrence of secretory canals in the shoot when they are absent in the root; it has also been shown that in those forms which have still other types of secretory organs, such as laticiferous vessels or secretory sacs, the secretory canals, so to say, withdraw into the lower organs of the plant and ultimately become confined to the root. These statements already serve to show that, when undertaking a systematic-anatomical investigation of the Compositae, an examination of the root is of primary importance, while, if possible, the entire vegetative organs should be examined from below upwards, in order to determine the distribution of the secretory canals, and of the internal secretory receptacles in general. As far as can be gathered from the literature, moreover, the secretory canals of the root are always distinctly endodermal in origin, while this is not always so in the case of the secretory canals of the axis. In many cases, it is true, the secretory canals are observed to originate in the endodermis in the axis also (see the examples mentioned in Col's Thesis, p. 99), the canals thus formed being for the most part narrow. In other cases, however, the secretory canals of the axis develop at a very early stage and have no connexion with the endodermis, which only appears subsequently; they seem to belong to the primary cortical tissue and are of wide diameter. This occurs very commonly in the Heliantheae, which sometimes have medullary canals as well, so that the secretory system of the axis, as in the case of *Silphium*, recalls that of the Umbelliferae.

The previous synopsis of the arrangement of the cauline resin-canals in relation to the fibrovascular system (see the second paragraph of small print on p. 461) has been extended and improved by Col, who likewise attributes systematic importance to these features; we can do no more than briefly refer the reader to pp. 90–3 of his thesis.

We may also point out here that in some cases in conjunction with repeated divisions in the endodermal cells the resin-canals of the root may occur in two or more rows, e. g. in *Platycarpha glomerata*, Less., *Arctotis stoechadifolia*, Berg and *Venidium calendulaceum*, Less.

It has already been mentioned in the earlier portion of this work (pp. 461, 462) that, side by side with the endodermal secretory canals, resin-canals have been demonstrated in other positions in the stem, rhizome, or root of certain members of the Order; these canals are situated in the primary cortex, in the periphery of the pith, in the secondary tissues (wood and bast) of the vascular system, or between the pericycle and the phloem. The earlier statements on this subject require a few additions and alterations. Col mentions the occurrence of medullary secretory canals in species of a few further genera, viz. *Baltimora*, *Carlina*, *Centaurea*, *Chrysanthemum*, *Cirsium*, *Cynara*, *Gaillardia* (rhizome), *Harpalium* (= *Helianthus*), *Podachaenium*, *Polymnia*, *Tridax* and *Zaluzania*, while the secretory organs present in the pith of the rhizome in *Inula Helenium*, L. and *Helenium autumnale*, L. are of the nature of cavities. Secretory canals are distributed in the secondary tissues of the vascular system as follows: (*a*) in the secondary bast: in the stem and root of *Helianthus tuberosus* and *Centaurea atropurpurea*, in the rhizome of *Carduncellus monspeliensium*, All., and in the root of *Kentrophyllum lanatum*, DC.; (*b*) in the medullary rays of the wood and bast: in the fleshy roots of *Dahlia*; and

(*c*) in the wood and bast: in the tubers of ***Helianthus tuberosus***. Secretory cavities are found in place of the secretory canals: (*a*) in the medullary rays of the bast: in the root and rhizome of ***Artemisia Dracunculus***, and in the subterranean organs of ***Atractylis gummifera***, L.; (*b*) in the medullary rays of the bast and wood: in the root of ***Anacyclus Pyrethrum*** and ***Carlina acaulis***; and (*c*) in the bast and wood: in the root and rhizome of ***Inula Helenium***.

We may replace the former synopsis (cf. p. 462) of the genera of Compositae in which the suhaerial parts of the plant contain no resin-canals, by the following enumeration taken from Col's thesis. The resin-canals do not penetrate into the suhaerial axis in species of: ***Acroclinium*** (= ***Helipterum***), ***Actinolepis***, ***Amblyolepis*** (= ***Helenium***), ***Ammobium***, ***Anaphalis***, ***Antennaria***, ***Anthemis*** (pro parte ?)[1], ***Arctotis***, ***Asteriscus*** (= ***Odontospermum***), ***Baeria***, ***Calendula***, ***Calocephalus***, ***Cardopatium***, ***Cephalophora***, ***Cryptostemma***, ***Cupularia*** (= ***Inula***), ***Dimorphotheca***, ***Echinops***, ***Elephantopus***, ***Ethulia***, ***Eurybia*** (= ***Olearia***), ***Evax***, ***Filago***, ***Gaillardia***, ***Gnaphalium***, ***Helenium***, ***Helichrysum***, ***Helipterum***, ***Humea***, ***Jasonia***, ***Inula*** (pro parte), ***Layia*** (?)[2], ***Leontopodium***, ***Leyssera***, ***Micropus***, ***Pallenis***, ***Phagnalon***, ***Pinardia*** (= ***Aster ?***), ***Podolepis***, ***Podotheca***, ***Rhodanthe*** (= ***Helipterum***), ***Rhynchopsidium*** (= ***Relhania***), ***Sphenogyne*** (= ***Ursinia***), ***Tarchonanthus***, ***Tripteris***, ***Venidium***, ***Vernonia*** pro parte (***V. anthelmintica***, Willd.), ***Xeranthemum***. To this list we may add the species of ***Achyropappus***, ***Madaria***, ***Madia*** and ***Schkuhria***, which have been examined, although in these cases the secretory canals are absent only from the upper parts of the axis. In the new enumeration, just given, the Cynaroideae which are provided with secretory sacs have not been taken into consideration (see under secretory sacs, below); moreover, the genera ***Centaurea***, ***Eupatorium*** and ***Madaria*** which were included in the earlier list have been omitted, since they possess secretory canals in the different parts of the axis; neither have I included the genera of the Labiatiflorae (Tribe Mutisiaceae), mentioned on p. 462 as having no resin-canals in the stem and leaf, since no new investigations dealing with this group have been published and the old statements retain their value. The number of species and genera, as yet examined in the various Tribes, is far too small to admit of a correct appreciation of the systematic value to be attached to the absence of the secretory canals in the subaerial organs. Yet it is a striking fact that resin-canals are wanting in the subaerial organs in all the Calendulaceae which have been investigated, as well as in those Inuloideae, which are included in the first seven subtribes (Tarchonantheae to Athrixieae) of Bentham and Hooker's system. But, on the other hand, we may also point out that, according to Col, within the limits of the genus ***Inula***, ***I. crithmoides***, L., for instance, has secretory canals in all the vegetative organs, while in ***I. hirta***, L., they are confined to the rhizome and are not found in the subaerial shoots.

As regards the occurrence of secretory canals (side by side with laticiferous vessels) in certain Cichoriaceae (cf. pp. 462, 463), we may add that they are present not only in ***Scolymus grandiflorus***, but also in ***S. hispanicus*** and ***S. maculatus***, that is to say in all the species of the genus (Col and Kniep). Doubling of the endodermis in the absence of resin-canals has also been observed in the root of ***Podospermum laciniatum*** (Col).

According to Feuilloux, **secretory cavities** (see p. 463) also occur in the leaf in numerous species of ***Athanasia*** (but not in ***A. leucoclada*** and ***A. pinnata***, L.), and, if I understand Paschkis rightly, they are present also in the mesophyll of ***Liatris odoratissima***, Willd. (= ***Trilisa odoratissima***, Cass.). It remains to investigate whether the cavities in these plants and in those formerly named take the place of the secretory canals in the leaf or whether they exist side by

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[1] According to Col. *Anthemis nobilis* has resin-canals in the base of the stem only.

[2] The base of the stem has not yet been investigated in this case.

side with them. For it has been shown that in other organs the secretory cavities are occasionally vicarious in their occurrence.

Secretory cavities have been observed in organs other than the leaf in the following Compositae: *Anacyclus Pyrethrum* (medullary rays of the wood and bast of the root); *Artemisia Dracunculus* (primary cortex and medullary rays of the bast of the root, medullary rays of the bast of the rhizome); *Atractylis gummifera*, L. (medullary rays of the bast of the subterranean organs); *Carlina acaulis* (medullary rays of the wood and bast of the root); *Cirsium lanceolatum*, Scop. (at certain levels in the stem in place of the secretory canals), *C. rivulare*, Link (in the rhizome, replacing the secretory canals); *Echinops Ritro*, L. and *E. sphaerocephalus*, L. (endodermis of the rhizome); *Gaillardia pulchella* (in the axis of the shoot to the right and left of the points of insertion of the leaves, somewhat of the nature of canals); *Helenium autumnale*, L. (pith, primary cortex, and endodermis of the rhizome); *Inula Helenium*, L. (bast and wood of the root and rhizome; in the latter also in the pith); *Inula britannica*. *I. Conyza*, DC., also *I. bifrons*, L. (endodermis of the rhizome); *Onopordon Acanthium*, L. (endodermis of the base of the shoot).

There is nothing to add regarding the **laticiferous vessels** of the Cichoriaceae (p. 463), but a few new facts as to the occurrence of these secretory organs outside this Tribe (cf. p. 463) have become known. Laticiferous vessels had previously been demonstrated in the pericycle and bast of the axis, as well as in the veins and ground tissue of the leaf in *Gundelia Tournefortii*, L., a member of the Arctotideae. Col has since found them in another genus of the Arctotideae (viz. in *Gazania splendens* × Hort. Angl.[1]) as well as in *Carlina* (Tribe Cynaroideae, Subtribe Carlineae[2]), while Kerckhoff records them in *Atractylis*, a genus very closely related to *Carlina*.

The laticiferous vessels of *Gazania splendens* show a primitive type of structure. Where the cells abut upon one another their longitudinal walls are locally resorbed, but true transverse bridges are not formed; some of the transverse walls, moreover, are persistent. Further, the laticiferous vessels of *Gazania* are confined to the pericycle of the axis and the veins of the leaf; in the root they are replaced by latex-cells, which are either isolated or arranged in longitudinal rows and are situated in the secondary bast. According to Kerckhoff, the laticiferous vessels of *Atractylis gummifera* are identical in structure with those of *Gazania*; they occur in the secondary bast of the subterranean parts of the plant, especially in the tap-root and in the axial parts of the root-stock. As regards *Carlina*, lastly, Col publishes the following details. In *C. caulescens*, Lam. the pericycle of the subaerial axis includes elements of the nature of laticiferous vessels, although their origin by fusion is very difficult to determine. In *C. acanthifolia*, All. the root and shoot contain laticiferous vessels composed of relatively short cells in which some of the transverse walls are not absorbed; these elements occur in the bast and pericycle respectively. The fact that in *Gazania* the laticiferous vessels are replaced by latex-cells and that *Carlina vulgaris*, L. has latex-cells only (in the pericycle of the axis) and no laticiferous vessels, indicates the close relationship of the two types of secretory elements. In order to complete the account of the secretory organs found in those genera which are provided with laticiferous vessels, we may mention that in *Gazania* endodermal secretory canals occur only in the root (in addition to the latex-cells in the bast already referred to above), that in *Atractylis* secretory cavities are found in the subterranean organs, and that *Carlina* has both secretory cavities and endodermal secretory canals,—the latter, for example, in the root of *C. caulescens* and in the root and axis of *C. vulgaris*.

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[1] Other members of the Arctotideae examined by Col do not possess these secretory organs, e.g. *Platycarpha*, in which endodermal secretory canals have been demonstrated in the root, and *Arctotis*, *Cryptostemma* and *Venidium*, which have endodermal secretory canals in the root only and not in the stem.

[2] In other members of the Subtribe Carlineae, which he investigated, Col did not observe laticiferous vessels, but merely rows of latex-cells, nor were these found in every case.

In place of the earlier statements regarding **secretory cells** with resinous or milky contents (see the first paragraph on p. 464) the following details may be inserted. The secretory sacs in question, which are often the cause of a very considerable exudation of milky juice from the organs in which they occur, are closely related to the laticiferous vessels by means of the transitional forms above discussed; they are for the most part much elongated, and, as a rule, occupy the same position as the laticiferous vessels, i.e. they are found on the inner side of the endodermis, external to the bast-groups of the vascular system. Whenever there is a development of primary hard bast, the secretory sacs are apposed to its outer side; in some cases they even penetrate into the group of primary hard bast itself or are embedded in it. In certain species the secretory sacs are found also at the periphery of the pith, very rarely in the bast as well. As regards their distribution we may first mention that they occur only in a few representatives of the Arctotideae and Vernonieae, but are more commonly found in the Tribe Cynaroideae; in the latter, however, they are confined to the Subtribes Carlineae and Carduineae (being absent in the Subtribes Echinopsideae and Centaureeae)[1].

Secretory sacs have been observed in the following species: I. In the tribe Arctotideae: in *Gazania splendens* (in the secondary bast of the root; for the laticiferous vessels present in the pericycle of the axis, see above). II. In the Tribe Vernonieae: in *Vernonia praealta* (outer portion of the primary bast of the root; pericycle of the rhizome; pith, primary cortex, and bast of the axis of the shoot; parenchyma of the veins and mesophyll of the leaf), *V. arkansana*, DC., *V. eminens*, Bisch., *V. flexuosa*, Sims., *V. noveboracensis*, Willd., but not in *V. anthelmintica*, Willd. III. In the Tribe Cynaroideae: 1. Subtribe Carlineae: in *Atractylis cancellata*, L. (pericycle of the axis), *Chardinia xeranthemoides*, Desf. (as in the preceding species), *Carlina graeca*, *C. racemosa*, L. and *C. vulgaris*, L. (as in the preceding species; for the laticiferous vessels of *C. acanthaefolia* and *C. caulescens* and the transitional forms related to them, see above). 2. Subtribe Carduineae: in *Alfredia* '*solenopis*' (? sphalm. ex '*stenolepis*'; pith and pericycle of the axis); *Arctium* '*lanuginosum*, DC.' (pericycle of the axis); *Berardia* (axis); *Carduus nutans*, L. and *C. tenuiflorus*, Curt. (pericycle of the axis); *Cirsium arvense*, Scop. (pericycle and pith of the upper parts of the axis and the leaves), *C. eriophorum*, Scop., *C. lanceolatum*, Scop., *C. monspessulanum*, All., *C. oleraceum*, *C. palustre*, Scop. and *C. rivulare*, Link; *Cousinia Hystrix*, C. A. Mey. (axis); *Galactites tomentosa* (pericycle and pith of the axis); *Jurinea alata* (axis); *Lappa minor*, DC. (pericycle and pith of the axis), *L. major*; *Onopordon Acanthium*, L. (pericycle and pith of the axis and leaf); *Silybum Marianum*, Gaertn. (pericycle of the upper parts of the axis, not in the leaf); *Staehelina dubia*, L. (pericycle of the veins of the leaf, not in the stem); *Warionia* (axis).

Within the limits of the Tribe Cynaroideae secretory sacs have been shown to be absent in species of *Cardopathium* and *Xeranthemum* (Subtribe Carlineae) and in species of *Cnicus* (*Chamaepeuce*), *Cynara* and *Saussurea* (Subtribe Carduineae), as well as in the Subtribes Echinopsideae (species of *Echinops*) and Centaureeae (species of *Carduncellus*, *Carthamus* incl. *Kentrophyllum*, *Centaurea* and *Serratula*).

Secretory sacs have not as yet been demonstrated in the root in any member of the Cynaroideae, as will be seen by reference to the synopsis given above; in certain species, moreover, they are confined to the upper regions of the shoot, viz. to the upper part of the axis and the upper leaves. The feature last mentioned of course very considerably restricts the value of the secretory sacs for practical systematic purposes; its explanation is to be found in the fact that in the more closely investigated Cynaroideae (belonging to the genera *Carduus*, *Carlina*, *Cirsium*, *Lappa*, *Onopordon* and *Silybum*), in which

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[1] It is very much to be desired that a more detailed investigation of the secretory organs in these Tribes and Subtribes should be undertaken on material from numerous genera.

the secretory sacs are accompanied by secretory canals, the two types of secretory organs are vicarious in their occurrence, inasmuch as the secretory sacs more or less replace the canals as one advances from the base towards the apex of the plant.

Thus in *Carlina vulgaris*, for example, the root contains endodermal resin-canals, which even penetrate into the lowest portions of the axis; higher up in the stem they are replaced by secretory cavities and ultimately by latex-cells situated in the pericycle. The rhizome of *Cirsium arvense* has endodermal and medullary resin-canals, which extend into the lower portion of the subaerial axis, but soon exhibit a decrease in number and at a higher level become crowded out by medullary and pericyclic secretory sacs. A similar relation, although it is not so marked, obtains between the secretory canals and the laticiferous elements in *Gazania* and *Vernonia*; this finds its expression in the fact that endodermal resin-canals occur only in the root (here side by side with laticiferous elements) and not in the stem, which is rich in latex.

To complete our synopsis of the secretory organs found in the Cynaroideae it remains to mention that those members of the Tribe which have no secretory sacs either possess secretory canals or have no secretory organs whatever. Secretory canals alone, not accompanied by laticiferous sacs, have been observed in: *Echinops* (Subtribe Echinopsideae, here confined to the root), *Cnicus*, *Cynara* and *Saussurea* (Subtribe Carduineae), and the investigated Centaureeae (see above); neither secretory canals nor secretory sacs are present in species of *Cardopatium* and *Xeranthemum* (Subtribe Carlineae).

In concluding the discussion of the secretory organs we have still to refer to the occurrence of ordinary cells of which the contents are resinous or resemble latex, although the cells are not differentiated as idioblasts. In some cases such cells appear to occur in place of secretory canals or latex-sacs.

To this category belong the elements found in *Echinops exaltatus* and *Tagetes patula* and described as resin-cells on p. 462, as well as the oil-containing endodermis of *Chaptalia tomentosa* referred to on the same page. Such cells are also found in the following species: *Barnadesia rosea* (bast of the root); *Cousinia Hystrix* (medullary rays of the wood and bast of the rhizome); *Eurybia argophylla*, Cass. (medullary and cortical parenchyma of the axis and petiole); *Staehelina dubia*, L. (in the bast (here tubular), and in the pericycle of the axis); *Tarchonanthus camphoratus*, L. (in the bast of the axis and leaf).

Among other forms of excretion of **oxalate of lime** (see p. 464) clustered crystals, some of which were of large size, were found by G. Fischer in numerous members of the Vernonieae and Eupatorieae (species of *Bolanosa*, *Eremanthus*, *Lychnophora*, *Pacourina*, *Vernonia*, etc.), and by Heering in species of *Baccharis*. Bundles of small acicular crystals occasionally (*Cirsium arvense*) occur also in the epidermis of the leaf. The small crystals covering the leaves in *Liatris odoratissima* consist of cumarin.

To the statements on the **structure of the leaf** (p. 464) we may add the following details. According to Greenman, the upper epidermis in *Senecio chalapensis*, Wats. var. *areolatus*, Greenm. is papillose. According to Grimm, *Vernonia Luschnathiana* has a two-layered hypoderm on the upper side of the leaf. The vascular system in the **veins** of the leaf frequently possesses a distinct parenchyma-sheath. For the occurrence of water-pores in the Compositae, see Spanjer, loc. cit.

New details as to the structure of the ground tissue and fibrovascular system in the **stem** of the herbaceous members of the Order are to be found in the papers of Keseling on *Achillea* Sect. *Ptarmica*, of Peter on *Scorzonera*, of Krüger on the Cichoriaceae, and of P. Wagner on *Senecio*. The structural variations, which can be employed for specific diagnosis, refer especially to the development of collenchyma and hard bast, the nature of the endodermis and of the tissue composing the medullary rays, and so on. According to

Möbius a feature deserving special mention is the peculiar occurrence of assimilatory tissue in the primary cortex of *Xanthium strumarium*; this tissue is confined to short strips on the stem, the epidermis above these strips alone containing stomata.

Septation of the **pith** has been observed by Harshberger and Greenman in the xerophilous species, *Senecio praecox*, DC., while in other species of *Senecio* the central portion of the pith commonly undergoes resorption. The dividing septa in *S. praecox* are formed by cells which store up water.

We will now turn our attention to the anomalous structure presented by the axis in many Cichoriaceae and certain representatives of other tribes, the previous description of which was comprised under the heading of '**medullary bundles**' (phloem- and vascular bundles, see p. 467). We may first mention that recent investigations dealing with these anomalies have been published by A. Peter (on *Scorzonera*), Krüger (on the Cichoriaceae), and Col (on the Tubuliflorae). In addition to the modifications previously described, a further one has been observed in certain species of the genus *Scorzonera*; in this case medullary vascular bundles do not stand out plainly in the transverse section of the stem, all the bundles being arranged in two or more not very distinct rings; a similar structure is met with also in certain species of *Centaurea*, e.g. *C. acaulis* and *C. alata* (see under 'cortical bundles,' p. 468). According to Peter and Krüger some of the manifold variations, found even within the limits of one and the same genus in the Cichoriaceae, are of value in specific diagnosis; in illustration of this statement the synopsis of these characters in the genus *Scorzonera* may be quoted from Peter's work.

The species of *Scorzonera* may be classified in the following four groups: I. Vascular bundles collateral with normal orientation (i.e. wood on the inner and bast on the outer side) and arranged in several indistinct rings, as seen in the transverse section of the stem: *S. eriosperma*, M. Bieb., *S. hirsuta*, L., *S. ensifolia*, M. Bieb., *S. nervosa*, Trev., *S. cretica*, Willd., *S. tomentosa*, L. II. Vascular bundles of unequal size, collateral, and normally orientated, showing a rather distinct arrangement in two rings: *S. rigida*, Auch., *S. pygmaea*, Sibth., *S. subaphylla*, Boiss., *S. ramosissima*, DC., *S. cinerea*, Boiss. III. Vascular bundles in a simple ring with normal orientation, the pith containing scattered strands of soft bast with or without a rudimentary xylem-mass, the medullary bundles in the former case being inversely orientated; in this group the peripheral vascular bundles are either (*a*) bicollateral: *S. latifolia*, Vis., *S. mollis*, M. Bieb., *S. elata*, Boiss., *S. hispanica*, L., *S. papposa*, DC., *S. incisa*, DC., *S. limnophila*, Boiss.; or (*b*) collateral: *S. aristata*, Ram. IV. Vascular bundles in a simple ring with normal orientation, medullary strands absent; the vascular bundles being either (*a*) bicollateral: *S. stricta*, Hornem., *S. inaequiscapa*, Boiss., *S. crocifolia*, Sibth., *S. macrocephala*, DC.; or (*b*) collateral: *S. lanata*, M. Bieb., *S. tuberosa*, Pall., *S. humilis*, L., *S. parvifolia*, Jacq., *S. sericea*, Auch., *S. villosa*, Scop., *S. austriaca*, Willd., *S. purpurea*, L., *S. cilicica*, Boiss., *S. eriophora*, DC.

To the list (p. 467) of Cichoriaceous genera, in which some of the species at least have medullary bundles (in the broader sense) in the stem, we may add *Hymenonema*; among the genera of Cichoriaceae in which medullary bundles are wanting we may include: *Aposeris, Haenseleria, Hispidella, Lagoseris, Lygodesmia, Metabasis, Notobasis, Podospermum, Richardia, Sonchus, Tragopogon* and *Urospermum*.

Outside the Cichoriaceae (see p. 468) medullary vascular bundles have been recorded by Col in *Cardopatium corymbosum* and *Kentrophyllum lanatum*. According to the same author the leaf-trace bundles in many Tubuliflorae exhibit strands of soft bast on their inner side prior to entering the ring of bundles, these strands occasionally joining up with the outer phloem in an annular manner; in some cases these intraxylary strands of soft bast continue their course on the inner side of the ring of bundles for some little distance (*Balduina multiflora*) or they may persist altogether (*Actinomeris alternifolia*).

To the category of **cortical vascular bundles** we may refer the bundles situated in the pericycle in *Achillea filipendulina* (according to Vuillemin), *Madia sativa*, *Atractylis cancellata* and species of *Anthemis* (according to Col), and the vascular bundles occasionally occurring in the cortex of *Helenium autumnale* (consisting of one large bundle with smaller ones arranged in a ring; likewise according to Col). We may also mention here the anomalous structure presented by the stem of *Cynara Cardunculus*, L., and *C. Scolymus*, L. The transverse section shows irregularly arranged vascular bundles which are of unequal size and occasionally lie together in groups of two or three; the bundles in these groups may have either the xylem- or phloem-portions directed towards one another. Cortical vascular bundles, lastly, are found not only in *Senecio Doria* (see the earlier part of this work), but also in *S. coriaceus*, Ait., and *S. macrophyllus*, M. Bieb., both belonging to the same subsection *Sarracenici* (P. Wagner).

Note (cf. p. 468). New examples of anomalous structure in the **root** have been observed in *Thrincia tuberosa*, DC. by Maige, Gatin, and Carano, and in *Atractylis gummifera*, L. by Kerckhoff. In the swollen parts of the adventitious roots, arising from the base of the stem in *Thrincia tuberosa*, the primary xylem-groups of the vascular system become surrounded by a meristematic ring, which is derived from the normal cambium and produces wood internally and bast externally. In this way the primary xylem-groups become transformed into steles.—The anomaly shown by the tap-root of *Atractylis gummifera* consists in the occurrence of successive concentric rings of vascular bundles in the wood. The bundles of the first ring show inverse orientation (the xylem being on the outside), those of the second ring normal orientation, those of the third again inverse orientation, and so on. In this way Kerckhoff was able to distinguish five rings of bundles in a root of some thickness. At certain points groups of vascular bundles belonging to the two inner rings unite to form actual steles. The anomalous structure just described can also be detected in an early stage of development in axial parts of the root-stock.

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CANDOLLEACEAE (STYLIDIACEAE) (pp. 469–471).

Burns's recent investigations on the structure of the axis and leaf in the genus *Stylidium* form a valuable extension of our previous knowledge.

The anomalous structure of the **stem** in *Stylidium adnatum*, R. Br., &c. does not, however, appear to be quite fully explained even by Burns's work. According to him the broad ring of sclerenchymatous fibres (some of which bear bordered pits in certain species) does not arise from an actual secondary meristem, but is merely a pericyclic strengthening ring, which adjoins the fibrovascular system on its outer side. The groups of soft bast and vessels, which are found enclosed in the sclerenchymatous ring in old vegetative stems of *S. adnatum* and *S. fasciculatum*, R. Br., are stated by Burns to belong to the leaf-trace bundles. According to the same authority the vascular bundles in the vegetative axes and peduncles are occasionally arranged in two rings; in other cases they are more irregularly distributed, much as in a Monocotyledonous stem. Their structure shows no uniformity in the relative positions of wood and bast; one meets with collateral vascular bundles accompanied by transitions to concentric bundles with central phloem; vessels may occasionally be observed in the phloem and now and then (e.g. in *S. calcaratum*, R. Br.) isolated vessels occur also in the pith. The strengthening ring above mentioned is 5 to 20 cells in thickness. In those species which have reduced leaves palisade-parenchyma composed of long cells is found in the stem.

Regarding the structure of the **leaf** in the species of *Stylidium* we may mention the following details. The **epidermis** always consists of a single layer of cells, although in many cases it appears to be composed of two or more layers. The apparent presence of several layers is due to the fact that the epidermal

cells (as is evident in longitudinal sections) are tall and are placed obliquely to the surface of the leaf; two or more epidermal cells are consequently cut through one after the other by a transverse section and seem to lie above one another. This phenomenon is connected with the prolonged apical growth of the young leaves. The shape of the imbricating cells varies from rhombic (e.g. *S. junceum*, R. Br.) to fibrous (*S. eriopodum*, DC., *S. pilosum*, Labill., etc.); their lumina may be rather wide (e.g. *S. saxifragoides*, Lindl.) or narrow, the cellulose-wall in the latter case exhibiting a correspondingly strong thickening (e.g. *S. eriopodum*, DC.). Owing to unequal growth in length the ends of the epidermal cells in some cases appear as uneven prominences on the surface (*S. scariosum*, DC.) or margin (*S. graminifolium*, Sw.) of the leaf. A typically one-layered and an apparently many-layered epidermis are found in species in which petiole and lamina of the leaf are differentiated (*S. calcaratum*, R. Br. and *S. petiolare*, Sond. with a one-layered epidermis; *S. pilosum*, Labill., *S. reduplicatum*, R. Br. and *S. saxifragoides*, Lindl. with an apparently many-layered epidermis), as well as in species, which do not show such a differentiation (*S. scandens*, R. Br., with a one-layered epidermis; *S. eglandulosum*, F. v. M., with an apparently many-layered epidermis). In certain species (e.g. *S. streptocarpum*, Sond.) the epidermal cells have a jagged outline in surface view, the apices of the angles in the notches being thickened. In some cases (specially distinct in *S. streptocarpum*) the lateral walls of the epidermal cells bear true bordered pits side by side with simple pits. The **stomata** show differences of structure within the genus *Stylidium*. In certain cases (as in *S. eriopodum*, DC.) the mother-cell of the guard-cells is formed by the first division in the dermatogen-cell. In most of the species (e.g. in *S. saxifragoides*, Lindl.) the development of the stomata takes place according to the Rubiaceous type, which is, however, occasionally somewhat obscured in the mature leaf. The distribution of the stomata on the surface of the leaf varies; for the most part they are found on both sides of the leaves, but in certain species they are confined to one side, which may be either the morphologically lower or the morphologically upper side, the latter under these circumstances being physiologically the lower side owing to twisting of the leaf; the latter case is found in the reduplicate leaves of *S. pilosum*, Labill. and *S. reduplicatum*, R. Br. In those species in which the apparently many-layered epidermis has a mechanical function owing to the sclerosis of its cells, the stomata are not equally distributed over the surface of the leaf, but occupy longitudinal band-shaped zones consisting of a single row of cells; thus, two such zones are found on either side of the leaf in *S. eglandulosum*, F. v. M. and *S. saxifragoides*, Lindl., while in *S. pilosum* and *S. reduplicatum* there are only two zones, which are confined to the morphologically upper side of the leaf. As a general rule the stomata are arranged with their pores directed parallel to one another and to the long axis of the leaf. The **mesophyll** is either centric with palisade tissue on all sides (e.g. in the acicular leaves) or more or less distinctly bifacial or almost homogeneous. Arm-palisade parenchyma, occupying either a vertical (*S. calcaratum*) or a horizontal (*S. eriopodum*) position, is occasionally distinctly differentiated. In *S. pilosum* the walls of the assimilatory cells are thickened and pitted, much as in the Cycads, and the same species has spicular cells, which function as a support to the epidermis. In the long-stalked leaves the **veins** show an abundant development of mechanical tissue around the vascular bundles, while in those leaves, in which the integumental tissue is sclerenchymatous, there is a reduction of the mechanical tissue in the veins.

Burns observed **oxalate of lime** in the form of clustered crystals in the ground tissue of the stem in certain species of *Stylidium* (e.g. *S. eriopodum*). The **hairy covering** in the genus *Stylidium* comprises glandular hairs (on the

axis of inflorescence and on the leaves) and mucilage-hairs (at the growing-points and in the axils of the leaves). The glandular hairs vary very much in shape. The small glands of *S. calcaratum*, R. Br., have a biseriate stalk and a bicellular head divided by a vertical wall; with them we may class the external glands found in *S. amoenum*, R. Br., *S. diversifolium*, R. Br. and *S. reduplicatum*, R. Br., in which the stalks are longer, though likewise biseriate, and the heads are divided by numerous vertical walls into a large number of approximately prismatic cells, which show a vertical arrangement. The glandular hairs of *S. pilosum*, Labill. and *S. lineatum*, Sw. exhibit a different type of structure: the first of these species has long club-shaped external glands provided with a biseriate stalk, which gradually merges into the head, the latter being divided by walls showing varied orientation; *S. lineatum* has glandular hairs with a long biseriate stalk and a spherical head, which is likewise divided by walls running in various directions. In the mucilage-hairs the structure of the head resembles that of the external glands found in *S. amoenum*, etc., but the stalk is uniseriate. In the simplest case (*S. adnatum*, R. Br.) the head of these mucilage-hairs consists of a varying number of rod-shaped cells, which are developed by a series of vertical divisions in the terminal cell of the young hair. These cells become detached from one another, while the cuticle is raised in a vesicular manner. With the bursting of the cuticle and the emission of the mucilaginous secretion the function of the mucilage-hairs in *S. adnatum* comes to an end. Other species, however, show certain points of difference from the case just described. The rod-shaped cells in the glandular heads of *S. pilosum*, Labill. first undergo transverse division into two cells; this leads to the bursting of the cuticle, remains of which persist at the base of the head. Thereupon the rays of the head (which are now bicellular) become enveloped by a new cuticle. In other species (e.g. *S. saxifragoides*) the transverse division of the cells and the formation of a new cuticle is repeated several times, so that a third or even fourth cuticle may be excreted, the remains of the old cuticles being found at the base of the individual cells in the rays of the hair.

Literature: Raunkjær, Cellekjærne-Krystalloider, Bot. Tidsskrift, xvi, 1887, pp. 41–5.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, p. 46.—Burns, Beitr. z. Kenntnis d. Stylidiaceen, Flora, 1900, pp. 313–54 and Tab. xiii, xiv; also Diss., Munich.

GOODENIACEAE (pp. 471–473).

Literature: Leisering, Interxyl. Leptom, Diss., Berlin, 1899, pp. 26, 27.—[Colozza, Studio anat. delle Gooden., Nuovo Giorn. bot. Ital., N.S., xv 3, 1907, pp. 304–26; see also the same author, *Brunonia*, loc. cit., pp. 296–303.]

CAMPANULACEAE (INCL. LOBELIACEAE) (pp. 473–476).

The distribution of the **laticiferous vessels** in the leaves **of the Campanuloideae,** Engler and Prantl has recently been determined from the systematic point of view, especially by H. Schmidt in connexion with his investigations[1] on the structure of the leaf in the group referred to. He met with laticiferous vessels in all the genera available for investigation, with the single exception of *Sphenoclea*—a genus which also differs from the rest of the Campanuloideae in the possession of large clustered crystals of oxalate of lime, and constitutes a special group (the Campanuloideae-Sphenocleae) in Schönland's system; *Ostrowskia* likewise has laticiferous vessels, as I have found by personal investigation. The correctness of Poulsen's statement as

[1] They deal with all the genera excepting *Ostrowskia*.

to the absence of latex in *Pentaphragma ellipticum*, Poulsen, is open to doubt, since H. Schmidt demonstrated laticiferous vessels in the larger veins of the leaf in P. *begoniaefolium*, Wall. The laticiferous tubes of the Campanuloideae are found in the bast both in the large and small veins, and frequently show fine examples of anastomosis. H. Schmidt observed penetration of the laticiferous tubes into the mesophyll, only in *Canarina*, where Trécul had previously demonstrated the same phenomenon ; so that the occurrence of these elements in the mesophyll is certainly very rare in the Campanuloideae.

Ydrac[1] has recently published observations on the **laticiferous system of the Lobeliaceae**. He records laticiferous tubes in species of *Centropogon*, *Clermontia*, *Cyanea*, *Delissea*, *Downingia*, *Haynaldia*, *Heterotoma*, *Isotoma*, *Laurentia*, *Lobelia*,[2] *Pratia*, *Sclerotheca*, and *Siphocampylus*. The principal system of anastomosing laticiferous vessels in these genera traverses the bast of the vascular bundles both in the stem and leaf. This principal system undergoes ramification, and from the branches of the first order ('rameaux laticifères') thus formed further branches ('branches laticifères') arise, which do not anastomose and are not developed by a process of fusion ; these branches are found in the ground tissue (pith and primary cortex), pericycle and wood of the stem, as well as in the mesophyll.

The following details regarding the **structure of the leaf in the Campanuloideae** are based on H. Schmidt's and Feitel's investigations. The **epidermal cells** as a rule are of medium size and relatively low ; their lateral walls may be straight or strongly undulated, while in some cases (e.g. in *Lightfootia juncea*, Sond., *Wahlenbergia robusta*, Sond.) the outer walls are considerably thickened. The cuticle is for the most part thin, its surface being smooth or striated, or more or less coarsely granular. In certain xerophilous species, especially those belonging to genera endemic in the region of the Cape (e.g. *Merciera*, *Microcodon*, *Roëlla*, *Wahlenbergia*), the upper epidermis in the middle of the surface of the leaf consists of cells with wide lumina and straight lateral walls, while towards the margin of the leaf the cells show a progressive decrease in size and have more or less undulated lateral walls. H. Schmidt records nodose thickenings at the points of intersection of the lateral walls in *Pentaphragma begoniaefolium*, Wall. and *Trachelium rumelianum*, Hampe. Papillose differentiation of the epidermal cells is of frequent occurrence, but according to H. Schmidt it always only affects isolated cells or (near the margin of the leaf) groups of cells ; a typical papillose epidermis was not observed in any species. The papillae are conical or hemispherical and in some cases are reduced to solid silicified knobs. A point deserving special mention is that gelatinized epidermal cells were not observed in any member of the Campanuloideae. The **stomata** as a general rule are not provided with special subsidiary cells. The only exception is furnished by *Pentaphragma* (*P. begoniaefolium*), which is distinguished also by the nature of its hairy covering (see below) and constitutes the group Campanuloideae-Pentaphragmeae in Schönland's system ; in this genus there are three narrow subsidiary cells. In the Campanulaceae investigated by Vesque, moreover, the mother-cell of the guard-cells is likewise not formed by the first division, but only appears after a few epidermal cells have been cut off from the dermatogen-cell. The stomata are found either on both sides of the leaf or only

[1] Ydrac also examined the structure of the root, stem and leaf. His investigations deal with the genera above enumerated, in which he studied the laticiferous system, as well as with the genera *Apetahia*, *Brighamia*, and *Rhizocephalum* (all the genera being taken in the sense of Durand's Index).

[2] Ydrac's statement (loc. cit., p. 106) that laticiferous tubes are absent in *Lobelia Dortmanna*, L., is incorrect, since the mesophyll in this species is traversed by a very well developed network of laticiferous tubes.

on the lower side; according to Wettstein *Hedraeanthus Pumilio*, Porta is exceptional in having the stomata confined to the upper side. The stomata generally lie on a level with the epidermis or are slightly raised or (rarely, e.g. in *Sphenoclea*) depressed. In the species provided with narrow leaves the pores of the stomata are placed parallel to the midrib. Water-pores are present in the majority of the species, but are mostly of no great size; varying numbers (for the most part 2–6) of these pores are associated with undulated epidermal cells to form groups, which are invariably found on the upper surface near the margin of the leaf and are occasionally situated on special prominences of the leaf-surface or on the leaf-teeth. The **mesophyll** may be centric, bifacial or homogeneous. A specially noteworthy feature, not previously recorded in this Order, is the occurrence of arm-palisade parenchyma, in species of *Adenophora, Campanula, Campanumaea, Canarina, Cephalostigma, Codonopsis, Heterocodon, Jasione, Leptocodon, Musschia, Ostrowskia* (according to my own investigation), *Pentaphragma* (*P. ellipticum*, according to Poulsen), *Peracarpa, Platycodon, Prismatocarpus, Symphyandra* and *Wahlenbergia*. Peculiar spongy tissue formed by rows of hypha-like cells and traversed by large intercellular spaces is found in *Lightfootia ciliata*, Sond., *L. fasciculata*, DC., *L. rubioides*, DC., &c. In *Wahlenbergia prostrata*, DC. the transverse section of the leaf, which is roughly four-sided, shows an extensive semilunar complex of aqueous cells with wide lumina, beneath the upper epidermis; below this hypoderm one first meets with spongy tissue and then with a single layer of palisade tissue. A similar hypodermal layer of aqueous tissue, which, however, in this case still contains chlorophyll, is found on the upper side of the leaf also in *W. capillacea*, DC. Other xerophilous members of the Order have a more or less strongly developed hypoderm composed of sclerenchymatous fibres, e.g. in certain species of *Cephalostigma, Lightfootia, Merciera, Microcodon, Prismatocarpus, Roëlla* and *Wahlenbergia*. This hypodermal sclerenchyma either merely forms crescent-shaped masses at the margin of the leaf, or extends somewhat onto the upper surface, where it ultimately gives rise to a continuous band of sclerenchyma. In some cases it is also found on the lower side of the leaf beneath the vascular system of the midrib, but separated from the latter by assimilatory tissue. Hard bast is not found accompanying the vascular bundles in the **veins** of the leaf in any member of the Campanuloideae. In its place the xylem-groups themselves occasionally include sclerenchymatous fibres, e.g. in species of *Lightfootia, Microcodon, Rhigiophyllum* and *Wahlenbergia*. In some cases the median vein is enveloped by a distinct parenchyma-sheath (e.g. in *Rhigiophyllum squarrosum*, Hochst.).

Oxalate of lime, which prior to this had been observed only in *Hedraeanthus*[1] by Wettstein, is found especially in the form of fine clustered crystals in *Sphenoclea*. H. Schmidt also met with small prismatic or acicular crystals of the same salt in the mesophyll of certain species of *Canarina, Heterochaenia, Leptocodon* and *Phyteuma*; crystals of this type are no doubt more widely distributed, but are easily overlooked. Sphaerocrystals of unknown chemical composition have been demonstrated also in species of *Adenophora, Canarina, Musschia, Phyteuma, Specularia, Symphyandra* and *Trachelium*.

Schmidt also failed to find any glandular hairs in the **hairy covering**. On the other hand, in *Campanumaea celebica*, Bl., he met with long conical clothing hairs composed of a single row of 4–7 cells with thin walls and wide lumina, while in *Pentaphragma begoniaefolium*, Wall., he observed multicellular clothing hairs with two or more arms; the latter consist of a short stalk,

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[1] Wettstein (loc. cit., p. 187) refers to the rare occurrence of crystals; he records clustered crystals in the stem of *H. serbicus*, Kern., and 'raphides' (probably not true raphides, see above) in the anthers of *H. Pumilio*, Porta.

one or more cells in breadth, and uniseriate arms, which are placed more or less parallel to the surface of the leaf and are composed of rather short cells, with moderately thick walls and wide lumina. For the rest, however, only unicellular clothing hairs have been found; these vary in length, in the thickness of their walls and in the width of their lumina, and have a smooth, striate, granular or verrucose surface. In most cases these hairs are pointed, rarely blunt (elongated and finger-shaped in *Codonopsis*; provided with a slightly swollen capitate end in *Phyteuma pinnatum*, L.). In the species of *Campanula* the walls of the hairs are commonly calcified and in some cases the neighbouring cells are raised to form a pedestal bearing the hair. The bases of the hairs, moreover, occasionally contain silicified protuberances resembling cystoliths; in certain species the latter occur also in the papillose and non-papillose epidermal cells of the margin of the leaf (being situated either in the corners or in the middle of the outer wall) or in the subsidiary cells of the hairs (in the same way as in *Lithospermum*).

For the occurrence of steles in the **petiole** of *Campanula rapunculoides*, see Bouygues, loc. cit.

With reference to the **structure of the stem in the Campanuloideae** we may add that according to Pitard the pericycle contains a ring of fibres only in *Platycodon*; at later stages stone-cells become intercalated in this ring.

The following account of the **structure of the leaf in the Lobeliaceae** is based on the results of Ydrac's work. The stomata are either confined to the lower side or occur on both sides; they have no subsidiary cells. Water-pores are present on the leaf-teeth. The mesophyll is bifacial or homogeneous. Oxalate of lime has not been observed. The hairy covering consists only of clothing hairs, which are generally unicellular (*Isotoma*, *Lobelia*, *Siphocampylus*) or uniseriate (*Pratia*, *Siphocampylus*) and have scarcely thickened walls, which frequently show a verrucose surface. A special form of hair is distinctive of *Siphocampylus Columnae*, i.e. tufted hairs having eight or more rays and seated on a multicellular stalk (see also Bentham and Hooker, Gen. Plant., ii, p. 548).

According to Ydrac the **structure of the stem in the Lobeliaceae** likewise shows very few striking features. The cork, which is rarely formed, arises in the outer parenchyma of the primary cortex (*Clermontia grandiflora*, Gaud. and *C. macrocarpa*, Gaud.), or in some cases in the subepidermal layer of cells (*Apetahia rajateensis*, Baill., *Lobelia excelsa*, Lesch., and *Siphocampylus biserratus*, A. DC.). The primary cortex is not uncommonly collenchymatous, while in *Downingia elegans*, Torr. and *Lobelia Dortmanna*, L. it contains large lacunae. In most cases the endodermis is distinctly developed and provided with Caspary's dots. The pericycle includes sclerenchyma (with wide lumina) only in *Lobelia Dortmanna*. There is no sclerenchyma in the soft bast. In *Pratia montana*, Hassk. and *Isolobus radicans*, A. DC. the fibrovascular system consists of two arcs of wood and bast. The cells of the pith may or may not be lignified; in some cases the central portion of the pith becomes resorbed and gives way to a lacuna (*Lobelia guadalupensis*, Urb., etc.).

According to Col **medullary phloem- and vascular bundles** occur also at some points in the stem of *Campanula rapunculoides*, and are present in the petioles and veins of the leaf not only in those members of the Order, which have axes with anomalous structure, but also in many which are normal. In the members of the Lobeliaceae, investigated by Ydrac, these bundles are absent. In the wood of the root of *Campanula pyramidalis* J. E. Weiss observed concentric vascular bundles, which form a continuation of the medullary bundles of the stem.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 161 et seq.—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.—Spanjer, Wasserapparate,

Bot. Zeit., 1898, i, p. 55.—Minden, Wasserser. Organe, Bibl. bot., Heft 46, 1899, pp. 23 and 34 (*Lobelia, Campanula*).—Baranetzky, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xii, 1900, pp. 295–9.—Feitel, Vergl. Anat. d. Laubbl. bei den Campanul. der Capflora, Bot. Centralbl., 1900, pp. 4, 41, 97, 129, and 161 et seq.; also Diss., Kiel (*Wahlenbergia, Lightfootia, Microcodon, Roella, Prismatocarpus*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 49.—[Baar, Milchröhr., Sitz. Ber. Lotos f. Böhmen, xxii, 1902, n. 4, 5.]—Bouygues, Pétiole, Thèse, Paris, 1902, pp. 13 and 73.—Poulsen, *Pentaphragma ellipticum*, Vidensk. Meddelels. Naturh. Forening, Kjøbenhavn, 1903, pp. 319–30, pl. iv, v.—Sylven, *Lobelia Dortmanna*, Arkiv för Bot., i, 1903, p. 377 et seq.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 19–97, 215 and 259–61.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 73, 74.—Paoli, Eterofillia, Nuovo Giorn. bot. Ital., N. S., xi, 1904, p. 227.—H. Schmidt, Syst.-anat. Untersuch. d. Bl. der Campanuloideen, Diss., Erlangen, 1904, 103 pp.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 43.—Haberlandt, Lichtsinnesorg., 1905, p. 70, Tab. 1.—Kniep, Milchröhr., Flora, 1905, pp. 169–71.—Mayus, Milchröhr., Beih. z. bot. Centralbl., xviii, Abt. 1, 1905, pp. 281, 282.—Theorin, Växttrichom., Arkiv för Bot., iv, n. 18, 1905, p. 21.—Ydrac, Appareil laticifère des Lobéliacées, Journ. de bot., 1905, pp. 12–20; also in Perrot, Travaux, ii.—Ydrac, Rech. anat. sur les Lobéliacées, 1905, in Perrot, Travaux, iii, 1906, 165 pp.; also Thèse, Paris.—Holtermann, Einfluss des Klimas, etc., 1907, Tab. ix, Fig. 45.—[For further literature, see p. 1169.]

VACCINIACEAE (pp. 476–479).

According to Poulsen extrafloral **nectaries**, appearing as disc-shaped structures with a raised rim, are found at the base of the lamina of the leaf in *Vaccinium Teysmanni*, Miq. They are provided with an irregular epidermis, below which lies a spherical complex of small-celled tissue in which the nectar is secreted, while the inner part of this tissue is enclasped by the ramifications of a vascular bundle which branches off from the petiolar system.

Literature: Latour, Séné, Thèse, Montpellier, 1894, p. 40 et seq.—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.—Poulsen, Extraflorale Nektarier, Vidensk. Meddelels. Naturh. For. Kjøbenhavn, 1897, pp. 365–8.—Roedler, Assimilator. Gewebesyst., Diss., Freiburg i. d. Schw., 1898–9, p. 37.—Petersen, Vedanatomi, 1901, pp. 81 3 (*Vaccinium, Oxycoccos*).—[For further literature, see p. 1172.]

ERICACEAE (pp. 479–488).

2. Structure of the Leaf. The most important recent work is Rommel's investigation of the structure of the leaf and stem in the Pyroleae (*Pyrola, Moneses* and *Chimaphila*) and in *Clethra*, and Linsbauer's paper on the detailed structure and course of development of the pocket-shaped leaves of *Cassiope tetragona* (cf. pp. 482, 483).

The structure of the leaves in the Pyroleae is either bifacial (*Pyrola* pro parte, *Chimaphila*) or homogeneous (*Pyrola* pro parte, *Moneses*), while in *Clethra* it is bifacial. *Clethra brasiliensis*, Cham. et Schlecht. has a single layer of hypoderm on the upper side of the leaf. Rommel's statement that the stomata in *Clethra* are invariably provided with two subsidiary cells, which are placed parallel to the pore, is incorrect, as I have found by an investigation of *C. arborea*, Ait. There is no sclerenchyma in the veins in the Pyroleae, whereas in *Clethra* it is found accompanying the vascular bundles. For the occurrence of rolled leaves in the Ericaceae and their structure, see also Knoblauch, loc. cit.

Oxalate of lime is present in the form of clustered crystals also in the Pyroleae and in *Clethra*. For the occurrence of nuclear crystalloids in the vegetative organs of *Pyrola* and *Chimaphila*, see Raunkjær, loc. cit.

In connexion with the section on the **hairy covering** we may specially draw attention to Boergesen's paper, which also deals with the mode of development of the hairs. Unicellular bristle-hairs are found in species of *Cassiope, Erica, Kalmia, Ledum, Loiseleuria, Menziesia, Phyllodoce* and *Rhododendron*, while multicellular woolly hairs occur in species of *Azalea, Clethra, Erica, Ledum, Leucothoë, Lyonia* and *Rhododendron*. Long club-shaped glandular

hairs composed of two rows of cells are present also in *Loiseleuria procumbens*, Desv. and *Phyllodoce coerulea*, 'Gr. et Godr.'; sessile external glands varying in shape from ellipsoidal to ovate and formed by a single row of cells, in *Cassiope tetragona*, Don; glandular hairs with a multiseriate stalk and a spherical head composed of numerous cells, in *Epigaea repens*, L.

3. STRUCTURE OF THE AXIS. Rommel's paper furnishes new data on the structure of the axis in the Pyroleae and in *Clethra*, while Petersen has recently examined the wood in a relatively large number of species.[1]

In the species recently investigated the **wood** likewise includes vessels which have relatively small lumina and are for the most part provided with scalariform perforations, while the ground-mass consists of wood-prosenchyma with bordered pits (tracheids). Spiral thickening of the walls of the vessels (at least of some of them) and tracheids is found in the species of *Arctostaphylos*, *Arbutus* and *Daboecia* cited below, as well as in *Chimaphila umbellata*, Nutt.[2]; wood-fibres bearing simple pits have been observed in *Moneses*, *Pyrola*, and *Arbutus Unedo*, L.

The perforations of the vessels are stated to be scalariform only in: *Andromeda polifolia* (with 10–20 bars, which are specially closely placed), *Cassiope tetragona*, *Chamaedaphne calyculata* (with delicate, closely placed bars), *Chimaphila umbellata* (bars not numerous), *Clethra* (with numerous bars), *Ledum palustre* (as in *Andromeda polifolia*), *Loiseleuria procumbens* (with numerous delicate bars), *Moneses grandiflora*, Salisb. (with numerous bars), *Phyllodoce coerulea* (with many bars), *Pyrola* (occasionally with 12–15 bars, which may anastomose in a reticulate manner), *Rhododendron lapponicum* (with as many as 10 bars, but mostly less; bars occasionally reticulate); simple perforations occur side by side with scalariform perforations having few bars in: *Arctostaphylos uva ursi* (scalariform perforations with one or two bars), *Calluna vulgaris* (small scalariform perforations, which may also have a reticulate structure); simple perforations only are present in: *Arbutus Unedo* (elongated elliptical), *Daboecia cantabrica*, *Erica Tetralix*.

In some of the species of *Pyrola* the **cortex** includes a ring of pericyclic sclerenchyma, which occasionally gives rise to radial processes penetrating between the vascular bundles; in *Moneses grandiflora* and in *Chimaphila*, on the other hand, there is no such sclerenchymatous ring.

Literature: [Paschkis, Pharmakogn. Beitr., Zeitschr. österreich. Apothek.-Ver., 1880, n. 27, 28; abstr. in Bot. Centralbl., 1881, i, p. 54.]—[Raunkjær, Krystalloider, etc., Vidensk. Meddelels. Naturh. For. Kjøbenhavn, 1882, p. 70; abstr. in Bot. Centralbl., 1883, ii, p. 267.]—Boergesen, Nogle Eric.-Haars Udvikl., Bot. Tidsskrift, xvii, 1890, pp. 307–14.—Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 58, 59.—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.—[Andersen and Kallstroem, Folia uva ursi, etc., Nord. Farm. Tidsskr., 1896, p. 33.]—Knoblauch, Ökolog. Anat. etc., Habilitat.-Schr., Tübingen, 1896, p. 5 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 19.—Holm, *Pyrola aphylla*, Bot. Gazette, 1898, p. 249.—Rommel, Anat. Untersuch, über d. Gr. d. Piroleae u. Clethraceae, Diss., Heidelberg, 1898, 53 pp. and 1 Tab.—Köhne, Papill. u. oberseit. Spaltöffn., Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 59 (Papillae in species of *Rhododendron*).—Linsbauer, Vegetationsorg. von *Cassiope tetragona*, Don, Sitz. Ber. Wiener Akad., cix, Abt. i, 1900, 18 pp., 2 Tab.—Paulesco, Struct. anat. des hybrides, Thèse, Genève, 1900, p. 73 (*Rhododendron*).—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 36–8.—Petersen, Vedanatomi, 1901, pp. 72–80.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 33 and 47 (*Erica*, *Arbutus*).—Simon, Sommer- u. wintergrüne Gew., Ber. deutsch. bot. Gesellsch., 1902, pp. 239–40.—Theorin, Växttrichom., Arkiv för Bot., i, 1903, p. 159.—[Györffi, Phys.-anat. Verh. von *Rhododendrum myrtifolium*, etc., Diss., Koloszvar, 1904 (Hungarian); abstr. in Just, 1904, i, p. 771.]—Andrews, *Epigaea repens*, Beih. z. bot. Centralbl., xix, i. Abt., 1905, pp. 314–20.—

[1] viz.: *Andromeda polifolia*, L., *Arbutus Unedo*, L., *Arctostaphylos uva ursi*, Spr., *Calluna vulgaris*, Salisb., *Cassiope tetragona*, Don, *Chamaedaphne calyculata*, Moench, *Chimaphila umbellata*, Nutt., *Daboecia cantabrica*, C. Koch, *Erica Tetralix*, L., *Ledum palustre*, L., *Loiseleuria procumbens*, Desv., *Phyllodoce coerulea*, Bab., *Rhododendron lapponicum*, Wahlenb.

[2] Rommel's statement as to the absence of vessels in the secondary wood of this species is incorrect, and the same applies to the record of the occurrence of a ring of sclerenchyma, etc. See also Petersen, loc. cit.

Kanngiesser, *Calluna vulgaris*, in Tubeuf, Naturwiss. Zeitschr., 1906, pp. 55–60.—Piccioli, Legnami, Bull. Siena, 1906, pp. 150 and 166.—Holtermann, Einfluss des Klimas, etc., 1907, pp. 76 and 115 (*Rhododendron*).—[Guttenberg, Immergr. Laubbl. d. Mediterranflora, in Engler, Bot. Jahrb., xxxviii, 1907, p. 434 (*Arbutus Unedo*).]

MONOTROPEAE (pp. 489, 490).

Literature: MacDougal, Symbiotic saprophytism (*Pterospora andromedea*, Nutt.), Ann. of bot., xiii, 1899, pp. 31–8.—Thomas, Feuilles sout., Thèse, Paris, 1900.—Porsch, Spaltöffnungsapparat, Jena, 1905, pp. 78–80.

EPACRIDEAE (pp. 490–494).

1. Review of the Anatomical Features. Bordered pits have also been observed on the walls of the fibrous cells in the pericycle and secondary hard bast (in the axis of many Epacrideae). The internal development of the cork (in the pericycle) constitutes an ordinal character. Oxalate of lime occurs in the form of solitary as well as of clustered crystals.

2. Structure of the Leaf. For the structure of the **epidermis**, see also Baccarini, loc. cit., p. 81 et seq. and Tab. IV; this author deals especially with the peculiar secondary thickenings of the cell-walls, which occur either on all the walls, or only on the outer, or on the outer and lateral walls or on the outer and inner walls; these thickenings are occasionally traversed by pits.

In the structure of the **mesophyll** we may specially note that according to Baccarini the palisade-cells show bellows-like foldings in very many species, and that spicular fibres ('tracheidi') extending up to the epidermis occur in *Andersonia aristata* and *A. parvifolia*. According to Baccarini the presence of bordered pits on the fibrous cells forming the sclerenchymatous sheaths of the **veins** is not a feature of such general distribution as was previously maintained by Simon.

Baccarini's paper contains data for the occurrence of **oxalate of lime** in the leaf, which very considerably add to our previous knowledge. Only solitary crystals are found accompanying the vascular bundles of the veins; in those species in which the veins have strongly developed sclerenchymatous sheaths (*Monotoca lineata*, etc.) the crystals are found in the epidermis. The mesophyll contains both solitary and clustered crystals. 'Macle scheggiate' (clustered crystals?) are recorded in *Epacris heteronema* and *E. pauciflora*, as well as in *Leucopogon flavescens* and *L. gracillimus*; short prisms are stated to occur in *Decaspora thymifolia* and *Styphelia triflora*, octohedral crystals in *Cyathodes dealbata* and *Dracophyllum verticillatum*, crossed twin-crystals in *Andersonia aristata*, *A. micrantha*, *Acrotriche cordata*, *A. serrulata*, etc. In *Prionotes* there is no oxalate of lime.

3. Structure of the Axis. New statements on the structure of the axis have been published by Lüders and Baccarini. The former, on whose investigations the following description is mainly based, examined species of all the twenty-six genera enumerated in Durand's Index, as well as *Woollsia* and *Sphenotoma*, which Drude regards as independent genera. No essentially new features have, however, been discovered.

We will first consider the structure of the **wood**. The vessels have relatively small lumina and are mostly arranged in distinct radial rows; a scattered arrangement is rarer. In the different species the perforations of the vessels are described as being exclusively simple or exclusively scalariform or both simple and scalariform; it still remains to be investigated whether those species which are stated to have simple perforations only, do not also possess scalariform perforations in the primary wood or in the neighbourhood of the latter. Anastomosis of the bars in the scalariform perforations frequently

leads to the production of reticulate or reticulate-scalariform types of perforation. The only additional species in which Lüders demonstrated the modified scalariform perforations, figured for *Epacris heteronema*, Labill. in Fig. 112, is *E. lanuginosa*, Labill., although Baccarini does not mention them (see also Rodham, in Ber. deutsch. bot. Gesellsch. 1890, p. 190); in these perforations the slits, which show a scalariform arrangement, are broken up into very small pores by numerous delicate and filiform bars. Lüders observed spiral thickening of the walls of the vessels in *Acrotriche aggregata*, R. Br., *Epacris paludosa*, R. Br., *E. purpurascens*, R. Br., *Lysinema ciliatum*, R. Br. and *L. elegans*, Sond.

Lüders found only simple perforations in the vessels in species of *Andersonia*, *Archeria*, *Asterolonia*, *Brachyloma*, *Coleanthera*, *Conostephium*, *Leucopogon*, *Lissanthe*, *Melichrus*, *Needhamia*, *Styphelia*; for the most part simple perforations, but accompanied by scalariform perforations with 2–5 bars or in some cases only a single bar, in species of *Acrotriche*, *Andersonia*, *Conostephium*, *Cyathodes*, *Leucopogon*, *Lissanthe*, *Lysinema*, *Melichrus* (malformed perforations), *Oligarrhena*, *Styphelia*; mostly scalariform perforations in *Monotoca* (with 2–6 bars); only scalariform perforations in species of *Cosmelia* (numerous bars), *Cyathopsis* (4–10 bars), *Dracophyllum* (15–20 or more bars), *Epacris* (mostly 4–15 bars, occasionally 1–3), *Lebetanthus* (numerous bars), *Pentachondra* (10–20 or more bars), *Prionotes* (numerous bars), *Richea* (10–20 bars), *Sphenotoma* (10–15 or more bars), *Sprengelia* (4–20 or more bars), *Trochocarpa* (2–12 bars), *Woollsia* (8–12 or more bars). See also Baccarini's statements on this point, loc. cit., p. 101.

The medullary rays are mostly one or two cells broad. Baccarini distinguishes two types of medullary rays in the wood of the Epacrideae. In the first type the medullary rays, which are one or two cells in breadth and vary from one to four cells in height, are composed of prosenchymatous cells (*Andersonia aristata*, *A. prostrata*, *Brachyloma ericoides*, *Coleanthera myrtoides*, *Epacris impressa*, *E. mucronulata*, *E. obtusifolia*, *E. pulchella*, *E.* '*splendens*,' *Woollsia pungens*); in the second type which is found in the majority of the Epacrideae, the cells of the medullary rays, as seen in longitudinal section, are rectangular and elongated in the vertical direction. The medullary rays of the second type occasionally attain a breadth of 4–5 or even (*Trochocarpa laurina*) eight cells. In some cases, however, both types of medullary rays are found in the same species (e.g. in *Epacris impressa*). The primary medullary rays of the bast frequently broaden outwards in the form of a wedge; this is the case in *Lissanthe montana*, R. Br., and *Monotoca scoparia*, R. Br. according to Lüders, and in *Leucopogon Richei* according to Baccarini. The wood-parenchyma [1] is, for the most part, not prominently developed, but is present in some quantity in *Prionotes cerinthoides* R. Br. according to Lüders, and in *Dracophyllum Urvilleanum*, *Epacris longiflora*, *Richea Gunnii*, and *Trochocarpa laurina* according to Baccarini. In certain species of *Acrotriche*, *Leucopogon*, and *Monotoca* chambered parenchyma containing crystals is found in the wood (Lüders). According to Lüders the entire wood-prosenchyma, constituting the ground-mass of the wood, bears bordered pits: according to the same authority, it is provided with a spiral band also in *Epacris paludosa*, R. Br. On the other hand, Baccarini also observed mechanical fibres bearing simple pits, although such cases are of rare occurrence (*Monotoca scoparia*, *Sprengelia incarnata*, *Woollsia pungens*, and species of *Epacris*).

Regarding the structure of the **cortex** the following details may be mentioned. In all cases in which the primary cortex had remained intact in the material employed for investigation (viz. in species of all the genera except *Acrotriche*, *Brachyloma*, *Needhamia*, and *Sprengelia*), Lüders was able to demon-

[1] Lüders' statement that the wood-parenchyma occasionally bears bordered pits, is probably incorrect and may perhaps be attributed to the presence of one-sided bordered pits on the walls of the

strate the presence of a continuous and composite ring of sclerenchyma or of isolated groups of sclerenchymatous fibres[1] in the pericycle, and of cork situated on the inner side of the latter. The fibres of the pericyclic sclerenchyma, like the sclerenchymatous fibres accompanying the vascular bundles of the veins (see p. 493 and Fig. 111, *C*), bear either bordered pits only (species of *Andersonia*, *Epacris*, *Lysinema*, *Woollsia*) or bordered pits side by side with simple pits (e.g. in species of *Conostephium*, *Dracophyllum*, *Leucopogon*, *Richea*, *Sphenotoma*). The cells of the cork have uniformly thickened walls, and in most of the genera do not show a distinct radial arrangement; the only exceptions in this respect are afforded by *Archeria*, *Lebetanthus*, and *Prionotes*. Lüders' investigations on the course of development of the cork in those cases in which the cork-cells exhibit an irregular arrangement, although not yet sufficiently extensive, have shown that a typical cork-cambium is really (cf. also p. 493) not present in these forms; regarding this point, see also Baccarini, loc. cit., pp. 96, 97. In many species repeated formation of cork takes place in the bast. In numerous members of the Order the secondary bast contains bast-fibres, which frequently constitute complete annular zones and give rise to a stratification of the phloem, while in other species they merely form groups of varying size. Bast-fibres were not observed in a number of species, but this may possibly be due to the slight thickness of the branch examined. According to Lüders the secondary bast-fibres in most members of the Order likewise bear bordered pits side by side with simple pits. In certain species the secondary bast contains chambered parenchyma with solitary crystals.

According to Lüders the **pith** in *Cosmelia*, *Dracophyllum*, and *Richea* contains relatively small cells, which are distributed in a reticulate manner between larger elements, while in *Dracophyllum* it includes peculiar crystalline conglomerates, which have a corroded appearance, and in some cases resemble clustered crystals; in other cases ordinary crystals of oxalate of lime occur in the pith. According to Baccarini the cells of the pith are occasionally collenchymatous (*Monotoca serrulata*) or provided with thin walls (*Leucopogon lanceolatus* and *L. amplexicaulis*); in *Coleanthera myrtoides*, moreover, they contain crystalline masses, which Baccarini regards as consisting of carbonate of lime, owing to their behaviour when treated with acetic acid (solution accompanied by an evolution of gas).

Literature: Lüders, Stammanatomie der Epacrid., Diss., Heidelberg, without date (1900–1), pp. 27–82 and Tab. ii.—Baccarini, Anatomia delle Epacrid., Nuovo Giorn. bot. Ital., N. S., ix, 1902, pp. 81–114 and Tab. iii–v.

DIAPENSIACEAE (p. 494).

Literature: Boergesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.

PLUMBAGINEAE (pp. 495–501).

To the previous account of the structure of the **leaf** (p. 499) we may add that in *Statice sinuata*, L. the cauline leaves develop palisade tissue and stomata on both sides, while the radical leaves have palisade tissue (of a reduced type) only on the upper side and stomata only on the lower side (Paoli). Redlich has demonstrated **cortical vascular bundles** (see p. 500) in additional species of *Armeria* and *Statice* (incl. *Goniolimon*), as well as in species of *Limoniastrum* (here the bundles only traverse the cortex for a very short distance).

[1] According to Baccarini there is no mechanical sheath in the pericycle in *Leucopogon revolutus*, *Oligarrhena micrantha*, *Monotoca serrulata* (= *Acrotriche serrulata*), and '*Andersonia media*.'

Literature: Redlich, Gefässbündelverlauf bei den Plumbag., Diss., Erlangen, without date (commun. to the university-library of Erlangen in 1896), 30 pp.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 19.—Wagner, Neuere Drogen, Diss., Erlangen, 1897, pp. 12–21 (*Plumbago*).—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, p. 12.—Paoli, Eterofillia, Nuovo Giorn. bot. Ital., N. S., xi, 1904, pp. 217–19.

PRIMULACEAE (pp. 501–506).

1. Review of the Anatomical Features. The following additions are necessary. Branched multicellular clothing hairs are found also in species of *Aretia, Coris, Dionysia*, and *Douglasia*. Oxalate of lime is absent only in the vegetative organs, since in certain members of the Order (e.g. *Coris, Glaux, Hottonia*, and *Primula*) the subepidermal layer of the testa contains crystals of this salt. Development of cork is rare, and takes place in different positions, viz. in the pericycle or in the superficial cell-layers of the primary cortex. Anomalous structure of the stem (more or less distinct polystely, combined with the occurrence of a 'réseau radicifère') is found also in *Bryocarpum* and *Dodecatheon*. Arm-palisade parenchyma has been observed in the mesophyll in species of *Lysimachia* and *Trientalis*.

2. Structure of the Leaf. The following supplementary details are taken from Decrock's work. In the xerophilous species, the **epidermal cells** are provided with straight lateral walls. The cuticle, in some cases, shows striation and punctation. The **stomata** are occasionally raised (*Cortusa Matthioli*, L., *Primula sinensis*, Lindl.), while in the xerophilous species, *Dionysia revoluta*, Boiss., they are confined to two furrows on the lower side of the leaf. Water-pores are found at the end of the median vein in all the Primulaceae, and in many cases may be met with at the ends of the larger lateral veins as well. The leaf is for the most part bifacial in structure, although centric leaves occur also among the xerophilous species. The **palisade tissue** consists of one or more layers of cells, which vary considerably in length. Decrock figures arm-palisade parenchyma composed of short cells in *Lysimachia punctata* and I have myself observed typical arm-palisade tissue consisting of short cells in *Trientalis europaea*, L. and *T. americana*, Pursh, and indications of arm-palisade cells in the first and especially in the second layer of the mesophyll in *Lysimachia nemorum*, L. The vascular bundles of the **veins** are occasionally provided with sclerenchyma.

According to Decrock those species which have a distinctly differentiated **petiole** exhibit only one vascular bundle at the point of insertion of the leaf. The petiole of *Primula rubra*, according to Bouygues, contains a median hemi-concentric vascular bundle, provided with a pith, and two lateral concentric bundles, devoid of a pith: each of these bundles is surrounded by a typical endodermis.

As regards the **hairy covering** the following facts deserve mention. Decrock also records branched hairs in *Aretia pubescens*, L. (side by side with unbranched hairs; for the trichomes of *Androsace* § *Aretia*, see also Jeanpert, loc. cit.), *Coris monspeliensis*, L. (on the calyx), *Dionysia* and *Douglasia Vitaliana*, Hook., whilst glandular hairs were demonstrated by him in species of all the 28 genera included in Pax's monograph. His statements as to the structure of the head of the external glands in the individual genera are unfortunately not sufficiently comprehensive; we may, however, note that in *Androsace villosa*, L., both unicellular and multicellular heads occur side by side. In *Hottonia palustris*, L. the heads of the glands are unicellular only, and not bicellular, as was stated on p. 503. From a systematic-chemical point of view it is interesting to note that the four species of *Primula*, in which Nestler demonstrated the presence of a secretion, having an irritating effect upon the skin (viz. *P. cortusoides*, L.,

P. obconica, Hance, *P. Sieboldii*, Morren, and *P. sinensis*, Lindl.), all belong to the section *Sinenses*.

3. STRUCTURE OF THE STEM. The structure of the **normal stem** in the Primulaceae has recently been investigated from two distinct sides, by W. Meyer and by Decrock, the two authors choosing different anatomical features as a basis for classification. Their results are briefly summarized in the following paragraphs.

In W. Meyer's system the presence or absence of a pericyclic strengthening ring is the chief character employed in classification. Other points taken into consideration are: the position of the strengthening ring (whether shifted towards the outside or towards the inside); and the relation of the vascular bundles to one another (whether the xylem-groups are united to form a ring by means of interfascicular wood, or the bundles are separated by unlignified or sclerosed medullary rays). W. Meyer records the presence of the strengthening ring in species of *Androsace*, *Aretia*, *Centunculus*, *Coris*, *Cortusa*, *Hottonia*, *Lysimachia*, *Primula*, *Samolus*, *Soldanella* and *Trientalis*, and its absence in species of *Anagallis*, *Androsace*, *Aretia*, *Cyclamen*, *Glaux*, *Gregoria* (= *Dionysia*), *Lysimachia*, *Primula* and *Soldanella*.

Decrock distinguishes three physiological types, corresponding to the exomorphic features presented by the shoot. They are as follows: I. Type *Primula*: Short shoot with radical leaves; endodermis normal, pericycle mostly parenchymatous, wood and bast forming a ring: *Androsace* pro parte, *Ardisiandra*, *Bryocarpum*, *Cortusa*, *Dodecatheon*, *Hottonia*, *Kaufmannia*, *Pomatosace*, *Primula* pro parte, *Soldanella*, *Stimpsonia*. II. Type *Lysimachia*: Rhizome with leafy shoots; primary cortex narrower than in I, soft bast less developed, pericycle in the subaerial shoots invariably sclerosed: *Anagallis*, *Apochoris*, *Asterolinum*, *Centunculus*, *Glaux*, *Lubinia*, *Lysimachia*, *Naumburgia*, *Pelletiera*, *Steironema*, *Trientalis*. III. Type *Aretia*: cushion-plants with acicular leaves; cortex exfoliating as far as the endodermis, which divides by radial and tangential walls, while its inner walls become thickened; bast present in very considerable quantity and collenchymatous; wood strongly developed with non-lignified wood-parenchyma: *Androsace* pro parte, *Aretia*, *Coris*, *Dionysia*, *Douglasia*.

For the structure of the tubers of *Cyclamen*, see Hildebrand, p. 97, and Decrock, p. 179 et seq. Regarding the aerating tissue in the primary cortex of *Lysimachia vulgaris*, L., see Witte, loc. cit.

Formation of **cork** (see p. 504) is rare, although a number of cases are mentioned by Decrock. The place of development of the cork varies; it may be the epidermal or subepidermal layer of cells (*Lysimachia Ephemerum*, L. and *L. vulgaris*, L., or *Dodecatheon*), the outer zone of the primary cortex (*Primula acaulis*, Jacq.), or the pericycle (*Douglasia Vitaliana*, Hook., *Primula bullata*, Franch.).

In dealing with the **anomalous structure** of the axis, I must, in the first place, refer once more to the anomalies which are shown by the stem in certain species of *Primula* (polystely and 'réseau radicifère'), and have been elucidated especially by Van Tieghem and Douliot (cf. pp. 504, 505). The groups which Van Tieghem establishes on the basis of these anatomical features do not coincide with the natural groups in Pax's system of classification. I append here an enumeration of the species of *Primula* which have a stem with anomalous structure (after Van Tieghem).

The members of the Officinales, Van Tieghem which have a 'réseau radicifère' are: *Primula acaulis*, *P. amoena*, *P. auriculata*, *P. elatior*, *P. elliptica*, *P. macrocalyx*, *P. malvacea*, *P. officinalis*, *P. petiolaris*, *P. sikkimensis*.

Among the members of *Auricula*, Van Tieghem, which likewise have a 'réseau radicifère,' *Primula reptans* still shows monostelic structure with a reduced pith. Polystelic structure occurs in the following modifications: (1) More or less numerous steles, which are either irregularly scattered or exhibit an annular arrangement and are fused at some points to form small arcs, in: *Primula algida*, *P. Allioni*, *P. angustifolia*, *P. Balbisii*, *P. calycina*, *P. carniolica*, *P. Clusiana*, *P. commutata*, *P. cuneifolia*, *P. daonensis*, *P. Delavayi*, *P. erosa*, *P. Floerkeana*, *P. glabra*, *P. glutinosa*, *P. hirsuta*,

P. integrifolia, *P. Kitaibeliana*, *P. latifolia*, *P. marginata*, *P. minima*, *P. minutissima*, *P. Muretiana*, *P. nivalis*, *P. Palinuri*, *P. Parryi*, *P. pedemontana*, *P. pubescens*, *P. spectabilis*, *P. tyrolensis*, *P. uniflora*, *P.* '*ursi*,' *P. venusta*, *P. viscosa*, *P. yunnanensis*. (2) Steles broadened in the shape of an arc, not numerous, and arranged to form a ring, in some cases fusing to form still wider arcs, in: *Primula amethystina*, *P. bella*, *P. calliantha*, *P. capitellata*, *P. Davidi*, *P. denticulata*, *P. Dickieana*, *P. farinosa*, *P. glacialis*, *P. Heydei*, *P. incisa*, *P. involucrata*, *P. longiflora*, *P. macrocarpa*, *P. Maximowiczii*, *P. membranifolia*, *P. Moorkraftiana*, *P. moupinensis*, *P. ovalifolia*, *P. pinnatifida*, *P. Poissoni*, *P. secundiflora*, *P. sibirica*, *P. sonchifolia*, *P. spicata*, *P. stricta*, *P. Stuartii*, *P. viscosa*. (3) Steles fused to form a more or less complete ring, the 'réseau radicifère' being almost absolutely annular, in: *Primula japonica*, *P. nutans*, *P. obtusifolia*, *P. prolifera*, *P. purpurea*, *P. serratifolia*. Decrock observed polystelic structure also in *P. capitata*, Hook., *P. Fauriae*, Franch. and *P. petiolaris*, Wall.

Anomalous structure of the stem, similar to that found in the Auriculas (viz. polystely, combined with the presence of a 'réseau radicifère') was observed by Decrock also in *Bryocarpum hymalaicum*, Hook. f. et Th. and *Dodecatheon Meadia*, L.; for details, see loc. cit.

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MYRSINEAE (pp. 507–512).

1. Review of the Anatomical Features. The following details may be added. The hypodermal sclerenchyma, which is a characteristic feature of the leaf in the Theophrasteae, is absent only in a small group of species of *Clavija*, and occurs also in the Tribe Eumyrsineae (viz. in *Weigeltia Schlimii*, Mez). In addition to the glandular hairs with a multicellular head, others with a unicellular head are exceptionally (*Jacquinia pungens*, Gray) found. New types of clothing hairs have been observed in certain species of *Jacquinia* in the form of multicellular trichomes, which are either forked or branched like antlers. The peculiar branched hairs previously described as occurring on the stem in *Jacquinia barbasco*, Mez (Syn. *J. armillaris*, Jacq.) are characteristic of two groups of closely allied species of *Jacquinia*. We may also note that gelatinization of the epidermis of the leaf is completely wanting in the Theophrasteae, and that the occurrence of crystals of oxalate of lime in the epidermis of the leaf in *Jacquinia* and *Deherainia* constitutes a generic character.

2. Structure of the Leaf. Votsch has recently published a careful

investigation of the structure of the leaf in the Theophrasteae in connexion with Mez's monograph in the 'Pflanzenreich.' The following details are abstracted from his paper and from the remaining literature.

In most of the Theophrasteae the **mesophyll** (cf. p. 507) is not differentiated into palisade and spongy tissue, although in certain species one or more layers of palisade tissue are found. The **epidermal cells** in the Theophrasteae, for the most part, have straight lateral walls. The cuticle is frequently strongly striated, rarely (species of *Jacquinia*) granular. Peculiar local thickenings of the walls of the epidermal cells showing distinct stratification and recalling the cystotyles of the Begonieae occur in *Clavija boliviensis*, Mez. *Theophrasta Jussieui*, Lindl. exhibits a peculiar calcification of the membranes of the epidermal cells; surface-sections of the epidermis, after being exposed to a red heat, show the cellular framework, which on treatment with sulphuric acid becomes transformed into needles of gypsum. A parenchymatous **hypoderm**, previously recorded in certain species of *Clavija* and *Jacquinia*, is rather widely distributed in these two genera, and occurs also in *Theophrasta Jussieui*, Lindl. As a general rule, it is confined to the upper side of the leaf, but in *Clavija Kalbreyeri*, Mez and *C. nobilis*, Mez it is found also on the lower side. The cells of the hypoderm are larger than those of the epidermis, only in *Clavija spathulata*, Ruiz et Pav.

According to Votsch a one-layered hypoderm is found in: *Clavija boliviensis*, Mez, *C. cauliflora*, Regel, *C. Hassleri*, Mez, *C. integrifolia*, Mart. et Miq., *C. Jelskii*, Szyszyl., *C. Lehmannii*, Mez, *C. longifolia*, Mez, *C. nobilis*, Mez, *C. parviflora*, Mez, *C. Poeppigii*, Mez, *C. Radlkoferi*, Mez, *C. Rodekiana*, Lind. et André, *C. serratifolia*, Mez, *C. spathulata*, Ruiz et Pav.; *Jacquinia aculeata*, Mez, *J. barbasco*, Mez, *J. brasiliensis*, Mez, *J. Eggersii*, Urb., *J. flammea*, Millsp., *J. linearis*, Jacq., *J. ovalifolia*, Mez, *J. pubescens*, H. B. K., *J. revoluta*, Jacq., *J. Schiedeana*, Mez, *J. Seleriana*, Urb. et Loes.; *Theophrasta Jussieui*, Lindl.; a 1–2-layered hypoderm in: *Clavija Schwackeana*, Mez; *Jacquinia keyensis*, Mez, *J. Sprucei*, Mez; and a typical 2-layered hypoderm in: *Clavija Kalbreyeri*, Mez and *C. Ruiziana*, Mez. A local development of hypoderm is found in the neighbourhood of the veins in *Clavija macrophylla*, Radlk. and *Jacquinia incrustata*, Urb., and near the margin of the leaf in *Clavija parvula*, Mez (see Votsch, pp. 14 and 34) and *C. tarapotana*, Mez.

If we adopt the synonymy given in Mez's monograph, the only species previously recorded (see p. 507) as having hypoderm, which are not included in the preceding list, are *Clavija spinosa*, Mez (formerly cited as *C. Riedeliana* and *C. caloneura*) and *C. umbrosa*, Reg., and, outside of the Theophrasteae, *Aegiceras majus*, Gaertn.

In *Myrsine heberdenia* some of the epidermal cells are subdivided by a horizontal wall, the lower cell, which is the larger of the two, occasionally including a crystal of oxalate of lime (Clauditz).

The **stomata** in the Theophrasteae are confined to the lower side of the leaf. In the species of *Jacquinia* they are deeply sunk, while in the other genera they project above the level of the epidermis by means of strongly developed horn-like processes. In the Theophrasteae the vascular bundles, both of the larger and smaller **veins**, are quite generally accompanied by sclerenchyma. In the genera of the Clavijeae, A. DC. (*Clavija*, *Theophrasta*, *Neomezia*) the median vein is traversed by two or more vascular bundles, while in the genera of the Jacquinieae, A. DC. (*Deherainia*, *Jacquinia*) it comprises only a single bundle. Among the Theophrasteae **oxalate of lime** has been observed only in *Clavija*, *Deherainia*, and *Jacquinia* (but not in *Neomezia* and *Theophrasta*); it is deposited as clustered crystals in *Jacquinia* only, while in all other cases it is found solely in the form of very small rhombohedral, prismatic, or acicular crystals. In *Jacquinia* and *Deherainia*, as well as in *Clavija serratifolia*, Mez, crystals of oxalate of lime (clustered in the case of *Jacquinia*) occur quite generally in the epidermis of the leaf, but are found also in the mesophyll.

The **sclerenchymatous hypoderm**, found in the Theophrasteae (see p. 509), has been subjected to a thorough re-investigation by Votsch. The most important result, from the systematic point of view, lies in the fact that this feature occurs in all the Theophrasteae with the exception of two small groups of very closely allied species of *Clavija*, namely: *C. Hassleri*, Mez and *C. Jelskii*, Szyszyl.; and *C. fulgens*, Hook. f. and *C. boliviensis*, Mez. In *C. integrifolia*, Mart. et Miq. the absence of the hypodermal sclerenchyma is only apparent, since in this species it is reduced to isolated fibres, lying near the vascular bundles of the veins. Votsch describes the hypodermal sclerenchyma in the following words: 'It consists of elongated fibres, which are strongly thickened (more rarely slightly thickened, as in *Clavija*), provided with oblique pits, and run independently of the sclerenchymatous sheaths of the vascular bundles. They are united to form larger (*Theophrasta, Neomezia, Jacquinia*) or smaller (*Clavija, Deherainia, Jacquinia*) bundles, or (more rarely, in *Clavija Rodekiana, C. serrata, C. grandis, Jacquinia aculeata, J. linearis*) are arranged in one-layered strata, in the latter case constituting sclerenchymatous plates.' In most of the Theophrasteae (especially in *Theophrasta*) the hypodermal sclerenchyma on the two sides of the leaf is joined by means of spicular fibres, which enter into connexion also with the sclerenchyma of the veins. In concluding the description of the hypodermal sclerenchyma of the Theophrasteae we may add that in *Weigeltia Schlimii*, Mez—the only species of the subgenus *Triadophora* (Tribe Eumyrsineae)—Mez observed sclerenchymatous fibres beneath the upper and lower epidermis of the leaf, just as in the Theophrasteae, and that Areschoug figures moderately elongated spicular cells of a parenchymatous shape in the mesophyll of *Aegiceras majus*, Gaertn.

In most of the Theophrasteae the **margin of the leaf** is strengthened by a single thick strand of sclerenchyma or by several sclerenchymatous strands, but in some species of *Clavija* (e.g. *C. biborrana*, Oerst., *C. grandis*, Decne., and *C. Lehmannii*, Mez) it is supported by a vascular bundle, from the sclerenchyma of which fibres are given off to the margin of the leaf; in a transverse section these fibres are cut through both longitudinally and transversely.

The section dealing with the **hairy covering** (see p. 509 et seq.) likewise requires a few important additions. Unicellular clothing hairs are wanting in the Theophrasteae; nor are uniseriate trichomes very abundantly developed on the leaves, although they are more commonly found on the vegetative axi and in the floral region. A transition to the characteristic branched trichome of *Jacquinia barbasco*, Mez (cf. Fig. 116 *c* on p. 510) is afforded by the un seriate hairs of *J. Schiedeana*, Mez, in which the terminal cell is divided by longitudinal wall. Peculiar branched trichomes, having thick walls and resen bling those found on the axis in *Jacquinia barbasco*, have been demonstrated b Votsch in the species included under Nos. 1–9 in Mez's monograph (*J. aculeat* Mez, *J. barbasco*, Mez, *J. Berterii*, Spreng., *J. brasiliensis*, Mez, *J. Eggersii*, Urb *J. incrustata*, Urb., *J. keyensis*, Mez, *J. linearis*, Jacq., *J. revoluta*, Jacq.) With these trichomes we may class the multicellular clothing hairs occurring the species of *Jacquinia*, described under Nos. 31–33 of Mez's monograph (vi *J. Seleriana*, Urb. et Loes., *J. Sprucei*, Mez, and *J. pubescens*, H. B. K.); the hairs are either dichotomously branched or resemble an antler in shap Glandular hairs have been observed only on the axis of *Jacquinia punger* Gray; they are not sunk, and are provided with a unicellular stalk and a u cellular head.

3. Structure of the Axis. According to Pitard a composite and cc

[1] According to Votsch (p. 531) trichomes of the same type as those found in *Jacquinia barb* occur also in *J. flammea*, Millsp. and *J. stenophylla*, Urb., while on pp. 521 and 524 they stated to be absent in these species. These contradictory statements remain to be explained.

tinuous ring of sclerenchyma is also developed in the pericycle in species of ***Ardisia***, ***Conomorpha***, and ***Embelia***. The statement as to the excretion of carbonate of lime in the lumina of the vessels in *Myrsine Grisebachii*, Hieron. must be cancelled, since, according to Mez, *M. Grisebachii* does not belong to the Myrsineae, but is a member of the Sapotaceae (*Chrysophyllum Grisebachii*, Mez). It remains to mention that, according to d'Arbaumont, the cells of the cortex and pith in *Myrsine africana* show a passing deep indigo-blue coloration on treatment with caustic potash.

For the structure of the terrestrial **roots** of *Aegiceras majus* (annular thickenings in the cells of the cortical parenchyma), see Karsten, loc. cit.

Literature: Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 56, 57.—Karsten, Mangrovevegetation, Bibl. bot., Heft 22, 1891, p. 50.—Boergesen og Paulsen, Vegetat. dansk-vestind. Öer, Bot. Tidsskrift, xxii, 1898–9, pp. 22, 23 (*Jacquinia armillaris*, Jacq.)—D'Arbaumont, *Myrsine africana*, Journ. de bot., 1900, pp. 361–8.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 64.—Areschoug, Mangrovepfl., Bibl. bot., Heft 56, 1902, pp. 55–7 and Tab. iv (*Aegiceras* [1]).—Claudits, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 28–31 (*Heberdenia, Pleiomeris* [2]).—Mez, Myrsinaceae, in Pflanzenreich, Heft 9, 1902, pp. 3, 4.—Mennechet, Poils épid. des Myrsin. etc., Journ. de bot., 1902, pp. 355–7.—Mez, Theophrastaceae, in Pflanzenreich, Heft 15, 1903, pp. 3, 4.—Votsch, Syst.-anat. Unters. von Blatt u. Axe der Theophrastaceae, in Engler, Bot. Jahrb., xxxiii, 1904, pp. 502–46; also Diss., Erlangen, 1903.—Joh. Schmidt, Verdens Mangrove træer, Bot. Tidsskrift, 1904, pp. 106–13 (salt-glands of *Aegiceras majus*).—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 133, 134 (*Theophrasta*), pp. 148, 149 (*Ardisia*), pp. 152–4 (*Jacquinia*).—[H. Weiss, *Aegiceras majus*, Diss., Strassburg, 1906; extract in Archiv d. Pharm. 1906, p. 221.]—Holtermann, Einfluss d. Klimas etc., 1907, p. 58 (*Aegiceras* .

SAPOTACEAE (pp. 512–515).

Engler records hypoderm in the **leaf** also in *Butyrospermum Parkii* (one-ayered), *Palaquium oblongifolium* (one-layered) and *Mimusops Commersonii* 3–4 layered), and sclerenchymatous fibres in the mesophyll in *Synsepalum lulciforme*, Daniell.

Engler observed 'one-armed' **hairs** with transitions to ordinary simple richomes on the ovary of *Malacantha Warneckeana*, Engl. and other species of his genus. According to the same authority simple unicellular hairs almost ompletely cover the different parts of the plant in *Delpydora*, Pierre.

Recent investigations on the **laticiferous elements** have been published y Charlier, who showed that the sacs are present in the root also (primary ortex and bast). According to Charlier, the occurrence of laticiferous sacs unning freely in the mesophyll is by no means so rare as has hitherto been upposed. In the root, the laticiferous sacs of the bast are arranged in longiudinal rows, which are united to form a network, or lie with their longitudinal valls apposed to one another, the common walls of contact in the latter case xhibiting thin areas ('laticifères anastomosées'); the laticiferous elements of he primary cortex, on the other hand, consist of rows of cells, which as a rule lo not enter into connexion with one another. In the axis, the bast likewise ontains 'laticifères anastomosées,' the longitudinal and transverse walls of vhich show thin areas, which are occasionally even perforated; Charlier thinks t not improbable that in the older axes these cells ultimately fuse to form a ystem of laticiferous vessels. The primary cortex and the pith for the most part nclude simple rows of laticiferous sacs only. The axis of certain species of *Bumelia* is particularly remarkable in containing groups of irregularly arranged

[1] In *Aegiceras* Areschoug records secretory cells instead of secretory cavities, which is no doubt mistake.

[2] In this paper the secretory cavities are likewise incorrectly described by Clandits as secretory cells.

laticiferous sacs, which undergo fusion at an early stage. In the case of the rows of laticiferous sacs occurring in the leaf, it is not certainly established whether absorption of the transverse walls really takes place occasionally. In some members of the Order isolated laticiferous sacs are found in the mesophyll, e.g. in the meshes formed by the network of the veins in *Sideroxylon brevipes*, Bak. (here side by side with groups of two or three laticiferous sacs). According to Charlier crystal-sand occurs especially in the laticiferous sacs of the leaf; it is rare in those of the axis, but is found in the sacs situated near the epidermis. It remains to mention that the genus *Tridesmostemon* likewise possesses laticiferous sacs.

For the excretion of carbonate of lime in the lumina of the vessels in *Chrysophyllum Grisebachii*, Mez, see under Myrsineae. Bargagli-Petrucci met with silica-bodies in the wood of *Palaquium* sp. and *Bassia crassipes*, Pierre.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 106 et seq.—Brandt, Wenig bek. Rinden, Diss., Dorpat, 1894, p. 9 et seq.—[Kempel, *Payena Leerii*, etc., Thèse de pharm., Moscow, 1898 (Russian); cited by Grélot and Charlier.]—Grélot, Caoutchoucs et Guttapercha, Thèse, Paris, 1899, p. 240 et seq.—[Obach, Guttapercha, Dresden, 1899.]—Ursprung, Anat. u. Jahresringbild., Diss., Basel, 1900, pp. 20–3 (*Imbricaria maxima*, Poir.).—Bargagli-Petrucci, Concrez. silicee, Malpighia, 1902, p. 23 et seq.; and Legnami, loc. cit., p. 360 et seq.—Fabricius, Laubblattanat., Beih. z. Bot. Centralbl., xii, 1902, pp. 306–8.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 121.—Engler, Sapotaceae, in Monogr. afrik. Pflanz.-Fam. u. Gatt., viii, 1904, pp. 2–5.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 37, 38 and Tab. v, vi (*Bassia*), pp. 106, 107 and Tab. xii (*Chrysophyllum*).—Charlier, Ét. anat. des pl. à Guttapercha, etc., Thèse, Paris, 1905, 160 pp.; also Journ. de bot., 1905 (*Achras*, *Argania*, *Bassia*, *Bumelia*, *Chrysophyllum*, *Hormogyne*, *Lucuma*, *Mimusops*, *Palaquium*, *Payena*, *Sideroxylon*).—Engler, *Tridesmostemon*, in Engler, Bot. Jahrb., xxxviii, 1905, p. 99.—Holtermann, Einfluss d. Klimas, etc., 1907, p. 179 (*Bassia*).—[For further literature, see p. 1172.]

EBENACEAE (pp. 516–519).

3. Structure of the Axis. Pitard records a composite and continuous ring of sclerenchyma in the pericycle in several species of *Diospyros* and in *Maba buxifolia*.

Literature: Knoblauch, Ökolog. Anat., Habilitat.-Schr., Tübingen, 1896, p. 21 et seq.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 82.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 361 (*Diospyros*).—[Wright, *Diospyros*, its morphology, anatomy, and taxonomy, Ann. Bot. Garden, Peradeniya, ii, 1904, pp. 1 and 133 et seq.; abstr. in Just, 1904, i, p. 769.]—Piccioli, Legnami, Bull. Siena, 1906, p. 141.—[Elsler, Extraflor. Nektar. u. Papill. d. Blattunterseite von *Diospyros discolor*, Willd., Anzeiger Wiener Akad., 1907, p. 419; and Sitz.-Ber. Wiener Akad., cxvi, Abt. 1, 1907, pp. 1563–90, 2 Tab.]

STYRACEAE (pp. 519–521).

The following new features have been observed: alumina-bodies in the mesophyll and cortex in the species of *Symplocos*; papillose differentiation of the lower epidermis of the leaf; development of hypoderm on the upper side of the leaf; differentiation of arm-palisade parenchyma; spicular fibres branching off from the sclerenchyma of the veins; secretory organs resembling intramural glands at the margin of the leaf or in the leaf-teeth; occurrence of solitary and clustered crystals in the epidermis of the leaf; hydathodes of peculiar structure. All these features have been recorded in certain species of *Symplocos*.

The structure of the leaf in *Symplocos* has recently been investigated by Cador and especially by Wehnert. The leaves in this genus are invariably bifacial. The palisade tissue consists of one or more layers, and in many species is differentiated as typical arm-palisade parenchyma, especially in the lower layers. The spongy tissue likewise shows diverse structure; in certain species it is composed of well-developed stellate cells, which (especially in the lower layers) are occasionally somewhat sclerosed. The **epidermal cells** have straight or undulated lateral walls. Gelatinization of the epidermis has not

been observed. Features deserving special mention are: the large epidermal cells found in *Symplocos confusa*, Brand; the epidermal cells of *S. polyandra*, Brand, with lateral walls bent in a zigzag manner and provided with ridge-like processes in the apices of the angles; the papillae on the lower side of the leaf of *S. neriifolia*, S. et Z., which are connected by means of cuticular ridges; lastly, the nature of the cuticle, which is either provided with delicate striae or with thick ridges, and often presents a very characteristic appearance (e.g. especially in *S. Itatiaiae*, Wawra). The **stomata** are confined to the lower side of the leaf, and are provided with two subsidiary cells placed parallel to the pore, as in the Rubiaceous type, the subsidiary cells in some cases undergoing transverse division. According to Wehnert a typical one-layered **hypoderm** is found beneath the upper epidermis in *Symplocos Hohenackeri*, Clarke, *S. microphylla*, Wight, *S. rubiginosa*, Wall., and *S. Stawelii*, F. v. M.; Holtermann records a hypoderm also in *S. obtusa* (continuous and often even consisting of two layers) and *S. spicata* (here locally developed). The vascular bundles of the lateral **veins** are sometimes vertically transcurrent on both sides of the leaf, or at least on the one side or the other. Wehnert demonstrated branching of the sclerenchyma of the veins, the branches penetrating into the mesophyll, in *S. neriifolia*, S. et Z. and *S. rubiginosa*, Wall., as well as in *S. colorata*, Brand. **Oxalate of lime** is excreted in the form of large or small solitary crystals, which are, for the most part, rhombohedral, although occasionally almost cubical, while in other cases it is deposited as clustered crystals; in certain species of *Symplocos* it occurs also in the epidermis of the leaf in the form of solitary and small clustered crystals. The only type of **trichome** found in *Symplocos* is that of simple sclerenchymatous clothing hairs provided with thin transverse walls. With these we may associate the peculiar hydathodes, observed by Wehnert on both surfaces of the leaf or only on the upper surface in *S. adenophylla*, Wall., *S. neriifolia*, S. et Z., and *S. tenuifolia*, Brand. These hydathodes are unicellular structures, having the shape of an inverted pistil; their outer end shows a bladder-like enlargement, while internal to this the hydathode is provided with a narrow neck, which is wedged into the centre of a rosette of 7–8 very small epidermal cells, and a slightly enlarged basal portion. The **secretory organs** above mentioned have been demonstrated at the margin of the leaf in *S. adenophylla*, Wall., and in the leaf-teeth in *S. glomerata*, King. They consist of rounded spaces, traversed by large numbers of elongated tubular cells, which form a secretion resembling gum, and are irregularly interwoven with one another; the structures thus recall the intramural glands found in *Psoralea*, and the glands of *Milletia*, &c. (see under Leguminosae).

The **alumina-bodies**, referred to above, were discovered by Radlkofer in the mesophyll of *Symplocos*; according to Wehnert they probably occur in all the species and are found in the cortex as well. In transverse sections of the leaf, cleared with Eau de Javelle (which should contain no carbonate of soda) they appear as grumose, pateriform, or placentiform bodies which are colourless, have an irregular angular or rounded outline, and are insoluble in water; they fill the greater part of the palisade-cells, in which several of these bodies lie one above the other, while they often take up almost the entire breadth of the cell; in appearance they are not quite unlike the deposits of solid fat, which occasionally occur in the cells of the leaf (Radlkofer, loc. cit., p. 216). According to Wehnert they assume a bright red colour after treatment with a weak alkaline solution of Brasilin, and are then easily recognized. We may add that in many species of *Symplocos* fat is met with in the epidermis and mesophyll.

The scalariform **perforations**, previously recorded as occurring in the vessels in *Symplocos*, were found by Wehnert to be of general distribution; the number of bars varies from 15 to 30.

Literature: Pierre, *Flore forest. de la Cochinchine*, xvii, 1892.—Lüdy, Sumatra-Benzoë, Diss., Bern, 1893, pp. 52–4.—Barthélemy, *Styrax officinalis*, Thèse, Montpellier, 1895, pp. 23–33.—Cador, Matéblätter, Bot. Centralbl., 1900, iv, pp. 248, 345 and 369 et seq.; also Diss., Erlangen.—Brand, Symplocaceae, in Pflanzenreich, Heft 6, 1901, p. 3.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 94.—Radlkofer, Tonerdekörper, Ber. deutsch. bot. Gesellsch., 1904, pp. 216–24.—Tschirch, Harzfluss, Flora, 1904, pp. 188–91.—Wehnert, Anat.-syst. Untersuch. d. Bl. d. Gatt. *Symplocos*, Diss., München, 1906, 57 pp.—Holtermann, Einfluss d. Klimas, etc., 1907, p. 118 (*Symplocos*).—[*Perkins, Styracaceae, in Pflanzenreich, Heft 30, 1907, pp. 5, 6.*]

OLEACEAE (pp. 521–526).

Papillose differentiation of the lower epidermis of the **leaf** (coronulate papillae united by a network of ridges) occurs only in three cases among the different species of ash, viz. in *Fraxinus americana*, L., *F. juglandifolia*, Lam. *(non Willd.) and F. Texensis*, Sarg. (Köhne). Spicular cells are also found in the mesophyll in *Olea Gardneri* and *O. laurifolia* (Holtermann, Gerhard). To the previous description of the external glands (see p. 523) we may add that in some cases (e.g. the glands on the buds of *Fraxinus Ornus*) they have a somewhat spherical head, divided by one or more vertical walls into the corresponding number of cells. Regarding the occurrence of extrafloral nectaries on the leaves of a species of *Fraxinus*, see Delpino, loc. cit

According to Baldacci the development of the **cork** takes place in the epidermis in *Forsythia europaea* (cf. p. 525). According to Pitard the **pericycle** also contains isolated groups of bast-fibres in *Fontanesia phillyraeoides* and *Forsythia suspensa*, while in *Chionanthus*, *Forestiera porulosa*, *Fraxinus*, *Jasminum*, *Linociera compacta*, *Olea americana*, *O. europaea*, and *Phillyrea* there is a composite and continuous ring of sclerenchyma; in *Jasminum* the latter does not persist for any great length of time, while in *Olea europaea* and *Phillyrea angustifolia* the sclerenchymatous ring is still found in axes of 4 cm. diameter, and in *Fraxinus excelsior* even in those of 35 cm. diameter. Möller's earlier statements on this point (see p. 525) refer for the most part to pieces of bark from old stems.

Literature: Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 53–5.—Stock, Proteinkrystalle, in Cohn, Beitr., vi, 1893.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—[Denniston, *Fraxinus americana*. Pharm. Archives, 1898, n. 1: abstr. in Just, 1898, ii, p. 13.]—Köhne, *Fraxinus*-Arten, in Wittmack, Gartenflora, 1899, pp. 282–8.—Baldacci, *Forsythia europaea*, Degen et Bald., Mem. Accad. Sc. Bologna, ser. v, t. viii, 1900, pp. 481–90 and tab. i, ii.—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 29–33.—Petersen, Vedanatomi, 1901, pp. 85–7.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 75, 76 and 86, 87.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 26, 27 (*Picconia*).—Gerhard, Blattanat. d. Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 24–6 (*Olea*).—[Armari, Piante della reg. medit., Annali di Bot., i, 1903, p. 17 et seq. (*Phillyrea*).]—[Delpino, Not. fitobiol., Bull. Orto bot. Napoli, i, 1903, p. 425 et seq.; abstr. in Just, 1903, i, p. 385.]—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 117.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 44.—Köhne, *Forsythia*, Gartenflora, 1906, p. 199 et seq.—Piccioli, Legnami. Bull. Siena, 1906, pp. 146, 154, 177, 178, 180, and 181.—Holtermann, Einfluss d. Klimas, etc., 1907, p. 119 (*Olea*).—[For further literature, see p. 1171.]

SALVADORACEAE (pp. 526–528).

For the structure of the leaf-spines of *Azima tetracantha*, see Lothelier. Interxylary phloem is found also in the root of *Salvadora*.

Literature: Möller, Rindenanatomie, 1882, p. 126.—Scott and Brebner, *Strychnos*, Ann. of Bot., iii, 1889, p. 296.—Lothelier, Épines, Thèse, Paris, 1893, p. 27.—Brandt, Wenig bek. Rinden, Diss., Dorpat, 1894, p. 18 et seq.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 23–6.—Holtermann, Einfluss d. Klimas, etc., 1907, p. 111 (*Salvadora persica*).

APOCYNACEAE (pp. 528–534).

1. Review of the Anatomical Features. The following additions are necessary. Gelatinization of the spongy tissue has been observed also in species of the genera *Carpodinus*, *Chilocarpus*, *Cylindropsis*, *Landolphia*, and *Willoughbeia*; hypoderm occurs also in the leaf of species of *Bousigonia*, *Carpodinus*, *Chavannesia*, *Chilocarpus*, *Ichnocarpus*, *Lepiniopsis*, *Leuconotis*, *Micrechites*, *Nouettea*, *Parabarium*, *Sclerodictyon*, *Willoughbeia*; papillae are developed on the lower side or on both sides of the leaf, as the case may be, in species of *Apocynum*, *Landolphia*, *Willoughbeia*; spicular fibres are found in the mesophyll in species of *Bousigonia*, *Micrechites*, *Neocouma*, *Sclerodictyon*, *Trachelospermum*. Bast-fibres, which are completely enveloped by crystal-cells, occur in Quebracho-bark. Secretory cells, forming a layer beneath the palisade tissue, are found in species of *Baissea*, *Echites*, *Kopsia*, and *Tabernaemontana*, mucilage-cells in species of *Apocynum*, *Carissa*, and *Ichnocarpus*, and lysigenous mucilage-cavities in species of *Bousigonia*, *Chonemorpha*, *Micrechites*, *Pottsia*, and *Rhynchodia*. Solitary crystals occur in the epidermis of the leaf in species of *Alstonia*, *Cerbera*, and *Hunteria*. Cork-warts are present on the leaves in species of *Carpodinus*, *Chilocarpus*, *Clitandra*, *Landolphia*, *Leuconotis*, and *Pycnobotrya*. Oxalate of lime is occasionally excreted also in the form of small solitary crystals.

2. Structure of the Leaf. The following additions to the earlier statements are principally based on the papers by Garcin, Hallier, Payrau, and Spire[1].

The **epidermal** cells of the leaf have lateral walls showing diverse structure and lumina of varying size. In the xerophilous species the cuticle is often strongly developed and frequently striated as well. Curved lateral walls provided with marginal pits are recorded by Hallier, for example, in all the species of *Landolphia*, with the exception of *L. gummifera*, K. Sch., while serrated cuticular prominences of quite a special type are stated to occur on the lower side of the leaf in *Melodinus orientalis*, Bl. Gelatinization of the inner walls of the epidermal cells has, curiously enough, not hitherto been observed in any member of the Order. In *Chonemorpha Griffithii*, Hook. (Spire) and *Chilocarpus costatus*, Miq. some of the upper epidermal cells of the leaf are divided by horizontal walls. **Hypoderm** is very widely distributed; it has recently been observed in the following additional species: *Ichnocarpus frutescens*, R. Br. (one-layered) and *Nerium odorum*, Soland. (3-layered on the upper side, 2–3-layered on the lower side) by Garcin; *Carpodinus lanceolatus*, K. Sch. (one-layered), *Chilocarpus suaveolens*, Bl., and *C. vernicosus*, Bl. (one layer of cells with wide lumina), *Chilocarpus* sp., Hose n. 3049, *Lepiniopsis ternatensis*, Valet. (one layer of cells with wide lumina), *Leuconotis anceps*, Jacq. (one or two layers of cells with wide lumina), *Micrechites micrantha*, Hallier f. (2–3-layered on the upper side, one-layered on the lower side), *M. polyantha*, Miq. (2–3-layered), *Sclerodictyon Griffonianum* (according to Pierre) and *Willoughbeia grandiflora*, Dyer (1–2-layered) by Hallier; *Bousigonia angustifolia*, Pierre, *B. mekongensis*, Pierre, *Chavannesia esculenta*, DC., *Micre-*

[1] Garcin investigated species of *Acokanthera* (*Toxicophloea*), *Alyxia*, *Amsonia*, *Apocynum*, *Carissa* (with *Arduina*), *Cerbera* (*Tanghinia*), *Echites*, *Forsteronia*, *Ichnocarpus*, *Mandevilla*, *Melodinus*, *Nerium*, *Plumiera*, *Rauwolfia* (*Ophioxylon*), *Tabernaemontana*, *Thevetia*, *Trachelospermum* (*Rhynchospermum*), *Vinca*; Hallier examined species of *Carissa*, *Carpodinus*, *Chilocarpus*, *Clitandra*, *Craspidospermum*, *Cylindropsis*, *Hunteria*, *Landolphia*, *Lepiniopsis*, *Leuconotis*, *Melodinus*, *Otopetalum* (= *Micrechites*), *Willoughbeia*, *Winchia*; Payrau examined species of *Strophanthus*; and Spire species of the Indo-chinese genera *Aganonerion*, *Amalocalyx*, *Bousigonia*, *Chonemorpha*, *Ecdysanthera*, *Melodinus*, *Micrechites*, *Nouettea*, *Parabarium*, *Parameria*, *Rhynchodia*, *Xylinabaria*. The investigations of Garcin, Payrau, and Spire deal also with the structure of the axis.

chites Jacqueti, Pierre (one-layered), *Nouettea cochinchinensis*, Pierre, *Parabarium Spireanum*, Pierre, *P. Tournieri*, Pierre and *P. Verneti*, Pierre (composed of large cells) by Spire; *Chilocarpus atroviridis*, Bl. (2-layered) by Areschoug. Papillae are distinctly differentiated on the lower side of the leaf in *Apocynum cannabinum*, L., *Landolphia ochracea*, K. Sch., and *Willoughbeia grandiflora*, Dyer, and on both sides of the leaf in *Apocynum androsaemifolium*, L. (Garcin and Hallier). The papillae found in *Willoughbeia grandiflora* show a peculiar type of structure ; they are narrow and columnar in shape, have narrow lumina, and bear two or more spherical heads, thus resembling a femur in appearance. Regarding the papillose prominences arising from the middle of the outer wall of the lower epidermal cells in *Vinca major* and *V. herbacea* (not in *V. minor*), see Haberlandt, loc. cit. : in these structures, which can scarcely be described as papillae, and which function as organs for the perception of light, the cellulose-layer is produced into a stopper-like process which penetrates into the cuticle. **Stomata** of the Rubiaceous type with a subsidiary cell situated to the right and left of and parallel to the pore have recently been demonstrated in species of *Carpodinus, Chilocarpus, Chonemorpha, Clitandra, Cylindropsis, Landolphia, Lepiniopsis, Micrechites* (with *Otopetalum*), *Parabarium, Strophanthus, Willoughbeia*, and *Winchia* ; on the other hand, stomata with three or four neighbouring cells are recorded in species of *Carissa, Craspidospermum, Ecdysanthera, Hunteria, Leuconotis, Melodinus*, and *Rhynchodia* (Hallier, Payrau, and Spire). The stomatal pits, characteristic of the common oleander, occur not only in this species, but also in *Nerium odorum*, Soland. Hallier describes stomata which are deeply sunk and have a vestibule above the guard-cells in *Leuconopsis anceps*, Jack and longitudinal ridges, covering in the pairs of guard-cells, in *Landolphia capensis*, Oliv. According to Hallier the gelatinization of the **spongy tissue**, first observed by Radlkofer in certain members of the Order, as a rule constitutes a specific character only ; it is widely distributed in the genera *Carpodinus, Chilocarpus, Clitandra, Cylindropsis, Landolphia*, and *Willoughbeia*[1]. In certain species of *Carpodinus, Chilocarpus, Melodinus*, and *Willoughbeia* fissures due to drying have been recorded in the palisade tissue. Spicular fibres, which have a varied course and branch off from the sclerenchyma of the veins, are found in *Bousigonia mekongensis*, Pierre, *Micrechites micrantha*, Hallier f., *M. polyantha*, Miq., *Neocouma ternstroemiacea*, Pierre, *Sclerodictyon Griffonianum*, Pierre, and *Trachelospermum jasminoides*, Lem. (Garcin, Hallier, Pierre, Spire).

According to Hallier **cork-warts**, like those found in *Pycnobotrya* (see p. 529), occur on the lower side of the leaf also in all true species of *Carpodinus* and *Chilocarpus* (in *Carpodinus ligustrifolius*, Stapf on the upper side as well), as well as in *Clitandra myriantha*, Pierre, *Landolphia owariensis*, Hallier f., *L. reticulata*, Hallier f., *Leuconotis anceps*, Jack, and *L. eugenifolius*, DC. The variations recorded in *Landolphia owariensis* are related to the more or less advanced stage of development of these structures.

The structure of the **petiole** has been examined in some detail by Garcin, Hallier, Pierre, and Spire. In *Nerium* the petiole is traversed by 5–7 vascular bundles, but in many Apocynaceae there are only three bundles, of which the two

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[1] The species in which this feature has been observed are as follows : *Carpodinus Barteri*, Stapf, *C. fulvus*, Pierre, *C. lanceolatus*, K. Sch., *C. leptanthus*, Stapf, *C. ligustrifolius*, Stapf, *C. maximus*, K. Sch. (vix !), *C. subrepandus*, K. Sch. (vix !), *C. turbinatus*, Stapf, *C. violaceus*, K. Sch. ; *Chilocarpus atroviridis*, Bl., *C. denudatus*, Bl., *C. suaveolens*, Bl., *C. vernicosus*, Bl. ; *Clitandra Buchanani*, Hallier f., *C. cirrhosa*, Radlk., *C. flavidiflora*, Hallier f., *C. gracilis*, Hallier f., *C. landolphioides*, Hallier f., *C. leptantha*, Hallier f. (vix !), *C. myriantha*, Pierre, *C. Schweinfurthii*, Stapf, *C. visciflua*, K. Sch. ; *Cylindropsis parvifolia*, Pierre, *C. togolana*, Hallier f., *C. Watsoniana*, Hallier f. ; *Landolphia bracteata*, Dew., *L. capensis*, Oliv., *L. crassipes*, K. Sch., *L. Eminiana*, Hallier f., *L. gummifera*, K. Sch., *L. Henriquesiana*, Hallier f., *L. lucida*, K. Sch., *L. ochracea*, K. Sch., *L. reticulata*, Hallier f., *L. scandens*, Didr. ; *Willoughbeia apiculata*, Miq., *W. grandiflora*, Dyer, *W. javanica*, Bl., *W. tenuiflora*, Dyer.

lateral strands are small and often show concentric structure; in other members of the Order again there is only a single vascular bundle in the petiole. Pierre attributes great systematic value to the nature of the principal vascular bundle, according as it forms (*a*) a tube which is either closed or only provided with a very narrow groove on its upper side, or (*b*) a mass of wood and bast which has a wide groove on its upper surface. Although Pierre goes too far in this respect, Hallier likewise describes a closed or barely open vascular tube as characteristic of the genus *Clitandra*, and a grooved mass of wood and bast as characteristic of *Carpodinus*.

We may next deal with the **hairy covering**. Uniseriate clothing hairs, similar to those figured for *Echites peltata*, Vell. in the earlier part of this work (p. 530), have been observed by Hallier also in *Micrechites polyantha*, Miq. The uniseriate hairs found in *Chonemorpha megacalyx*, Pierre are remarkable, since the upper epidermis of the leaf consists of several layers near the point of insertion of the hair, while the lower epidermal cells and those situated above the veins are prolonged onto the basal portion of the hair, occasionally even forming true cushions (Spire). According to Valeton (see also Mirabella) the glandular shaggy hairs, already mentioned, are present in very many members of the Order, being situated on the interpetiolar line between the opposite leaves and on the inner side of the petiole.

In addition to the forms of excretion of **oxalate of lime**, previously observed (p. 530), small prismatic crystals occur in certain Apocynaceae (e.g. species of *Aganonerion*, *Parabarium*, *Xylinabaria*, &c.). An investigation based on more abundant specific material can alone settle how far the occurrence of solitary crystals only, or of clustered crystals only, or of both forms side by side are features which can be employed in generic diagnosis. We may, however, mention that Hallier, for instance, records only solitary crystals in the mesophyll in *Clitandra* and *Landolphia*, and clustered crystals in the spongy tissue in most of the species of *Melodinus* and in all the species of *Hunteria*, and that, according to Garcin, oxalate of lime appears to be wanting in *Apocynum*. The solitary crystals found in the mesophyll are occasionally of large size, and in *Landolphia gummifera*, K. Sch. and *L. crassipes*, K. Sch., for example, they occupy the whole thickness of the leaf; large idioblasts, containing clustered crystals, and giving rise to transparent dots in the leaf, are found in *Hunteria africana*, K. Sch. Another important systematic feature is the occurrence of solitary crystals in the epidermis of the leaf in certain members of the Order; apart from the species previously mentioned in this connexion (*Alstonia scholaris* and *Cerbera Manghas*), this character is found in all the species of *Hunteria* (according to Hallier), in *Cerbera Tanghin*, Hook. (according to Garcin), and in *Gonioma Kamassi* (according to Gerhard).

To the section dealing with the non-articulated **laticiferous tubes** we may add the following details. In the first place we may note that Spire mentions the occurrence of anastomoses in the laticiferous system of the axis, the leaf, the floral parts and the fruits of certain Apocynaceae. He observed only two examples of anastomosis in the axis, viz. in the laticiferous tubes situated in the pericycle of '*Alstonia Hoedtii*, F. et B.,' and in the case figured by him in Fig. 1, pl. XXXVI (*Cercocoma macrantha*, Teijsm. et Binn.). The first case did not admit of verification; the second, judging by the figure, is merely an instance of apparent anastomosis, which can be brought into relation with the branching of one of the non-articulated laticiferous tubes. On the other hand, Figs. 1, 4, and 5 on pl. XXXIV, which refer to the laticiferous tubes in the petals of *Rhynchodia Capusii*, Pierre, *Aganosma marginata*, Don and *Parabarium Verneti*, Pierre, appear to show true anastomoses. According to Spire, however, anastomoses in the floral organs and fruits are likewise of rare occurrence. *Leuconotis eugenifolius*, DC. and '*Ochrosia glomerata*' are given as examples

of the occurrence of anastomoses in the leaf. A careful reinvestigation of these cases of anastomosis is very much to be desired. With reference to the distribution of the laticiferous tubes in the axis we may add that they occur abundantly also in the pericycle. Laticiferous tubes running freely in the mesophyll have been observed in the following additional species: in *Acokanthera spectabilis*, Hook. by Garcin; in *Chilocarpus denudatus*, Bl., *Dipladenia atropurpurea*, 'Müll. Arg.,' *Parabarium latifolium*, Pierre, and *P. Tournieri*, Pierre by Spire[1]; in *Hunteria ambiens*, Hallier f., *H. pleiocarpa*, Hallier f., *H. pycnantha*, K. Sch., *Lepiniopsis ternatensis*, Val., *Leuconotis anceps*, Jacq., and *L. eugenifolius*, DC. by Hallier. For the distribution of the laticiferous tubes in the petiole and in the veins of the leaf, see especially Spire, loc. cit., p. 155. The diameter of the laticiferous elements varies with the species and with the tissue in which they occur. The largest diameter is 50 μ (laticiferous tubes in the pith of *Heligme buruensis*, Teijsm. et Binn.), the smallest 5–7 μ (cortex of *Landolphia Kirkii*, Dyer). The secretion is not always white, but may be bright yellow (*Leuconotis eugenifolius*, DC.) or pale red (*Parabarium, Parameria*) or greenish (*Trachelospermum jasminoides*, Lem.). Starch-grains were observed by Molisch in the latex only in *Nerium Oleander*, L. and *Allamanda Schottii*, Pohl; the same authority found small crystalloids in the latex of the oleander, and indican in the latex (as well as in the mesophyll) of *Echites religiosa*, Teijsm. et Binn. The walls of the laticiferous tubes for the most part consist of cellulose, but are occasionally suberized.

The previous list of Apocynaceous genera, in which non-articulated laticiferous tubes and intraxylary phloem have been shown to occur (see footnote on p. 531), may be amplified by the addition of the following genera on the basis of Garcin's, Hallier's, and Spire's investigations: *Acokanthera, Aganonerion, Amalocalyx, Bousigonia, Carpodinus, Chilocarpus, Chonemorpha, Clitandra, Craspidospermum, Cylindropsis, Ecdysanthera, Hunteria, Lepiniopsis, Leuconotis, Micrechites, Nouettea, Parabarium, Rhazya, Winchia* and *Xylinabaria*. Spire records laticiferous tubes also in species of *Aganosma, Cameraria, Holarrhena, Kickxia, Roupellia, Vallaris* and *Voacanga* (under *Orchipeda*). We may add here that according to Spire Blondel's statement (Connessie, in Les nouv. remèdes, 1887, p. 427) as to the occurrence of transverse walls in the laticiferous tubes of *Holarrhena antidysenterica*, Wall. is incorrect.

In addition to the non-articulated laticiferous tubes other types of internal **secretory organs** (viz. secretory cells with contents resembling latex, mucilage-cells and mucilage-cavities) are found in certain members of the Order. Secretory cells were already previously (p. 531) mentioned as occurring in *Aspidosperma Quebracho*, Schlecht., and *Geissospermum Vellosii*, Peck. According to Spire the following elements belong to the same category: (*a*) cells filled with granular contents and forming a complete layer below the palisade tissue in *Cleghornia cymosa*, Wight (= *Baissea acuminata*, Benth.), *Echites religiosa*, Teijsm. et Binn., *Kopsia fruticosa*, DC., and *Tabernaemontana sphaerocarpa*, Bl.; (*b*) the isodiametric secretory cells found in the floral organs in species of *Aganosma* and *Melodinus*; and (*c*) the elongated secretory cells present in the fruits of *Melodinus* and *Tabernaemontana*. Garcin observed mucilage-cells in *Apocynum venetum*, L. (pith, bast, and primary cortex), *Carissa Arduina*, Lam. (primary cortex and spongy tissue), *C. Carandas*, L. (subepidermal cell-layer of the cortex), *C. ovata*, R. Br. (primary cortex, pericycle and tissue of the leaf), and *Ichnocarpus frutescens*, R. Br. (pericycle). According to Spire the mucilage-cavities are lysigenous in origin, although surrounded by an epithelium, and are occasionally of very considerable width. They are found at the margin of the pith or in the intraxylary phloem in *Bousigonia angustifolia*, Pierre, *Chone-*

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[1] Spire's remaining statements (loc. cit., p. 156) concerning this point are not clearly presented.

morpha Grandieriana, Pierre, *C. megacalyx*, Pierre, and *Micrechites Jacqueti*, Pierre, and in the pith, outer portion of the bast, and wood, as well as in the parenchyma of the leaf in *Rhynchodia Capusii*, Pierre and *Pottsia cantonensis*, Hook. et Arn.

Greshoff has shown that the demonstration of the presence or absence of alkaloids in a member of the Apocynaceae by means of microchemical tests may also be of importance in the solution of systematic problems (see Hallier, loc. cit.).

3. Structure of the Axis. To the statements on the structure of the **wood** we may add that the wood-prosenchyma bears bordered pits also in *Aspidosperma* (Hansen).

As regards the structure of the **cortex** we may first note that the cork develops in the epidermis also in species of *Acokanthera*, *Amsonia*, *Melodinus*, and *Trachelospermum*, in the subepidermal layer of cells in species of *Carissa*, *Ecdysanthera*, *Melodinus*, *Micrechites*, *Parabarium*, and *Xylinabaria*, and in a slightly deeper layer of cells in certain species of *Parabarium* and *Xylinabaria* (Garcin, Spire). The phelloderm is occasionally sclerosed (*Alstonia constricta*, F. v. M.) or its cells are filled with solitary crystals (*Alstonia scholaris*, R. Br.). The primary cortex frequently includes stone-cells or groups of these elements; in some cases there is even a ring of stone-cells (e.g. in *Micrechites Jacqueti*, Pierre, according to Spire). In *Forsteronia corymbosa*, Mey. an annular zone containing clustered crystals is found in the cortex. The groups of pericyclic bast-fibres are frequently arranged in one or more annular zones; in other cases they lie singly, or in small scattered groups in a broad pericycle, or unite to form a ring. Side by side with the bast-fibres, the walls of which are often not lignified, the pericycle contains crystal-cells, stone-cells and laticiferous tubes. Spire's statement as to the absence of pericyclic fibrous cells in *Amalocalyx microlobus*, Pierre is probably based on the investigation of a branch of slight thickness, since the differentiation of bast-fibres in the pericycle of the Apocynaceae often takes place only at a late stage; a reinvestigation is required to determine whether the ring of stone-cells, recorded by the same author in the pericycle of *Bousigonia mekongensis*, Pierre, really belongs to the pericycle. Hard bast seems to occur more frequently in the secondary phloem than was formerly supposed, judging by the statements of Garcin with reference to *Alstonia scholaris* and *A. constricta*, and of Spire with reference to *Bousigonia mekongensis*. In *Aganonerium polymorphum*, Pierre the secondary bast contains a ring of stone-cells (Spire). The bast-fibres of the Quebracho-bark, which either occur embedded in groups of stone-cells or lie isolated, are quite specially distinguished by the fact that each fibre is completely enveloped by a one-layered sheath of crystal-cells, each of which contains a solitary crystal (Hansen, Möller, Garcin, &c.); according to Möller the only other known example of this type of structure is found in 'Cortex Chinae albae de Payta.'

The mode of development of the **anomalous structure** of the axis found in *Condylocarpon* sp. (see Fig. 123 on p. 533) has been investigated by Leisering; according to him the enclosure of the phloem-groups is not due to the activity of a new cambial arc (as in *Strychnos*), but to proliferation of the tissue of the wood. With reference to the interxylary phloem of *Lyonsia straminea*, the same author states that the cambium at first merely produces groups of thin-walled parenchyma on its inner side, and that the transformation of these groups into leptome takes place at a later stage[1].

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[1] The statement (in Perrot, Tissu criblé, Thèse, Paris, 1899, p. 186) to the effect that interxylary phloem occurs in *Apocynum cannabinum* and *Willoughbeia firma* is incorrect, cf. Scott and Brebner, in Ann. of Bot., 1891, p. 283 et seq.; these authors only mention the secondary transformation of the intraxylary phloem-bundles into inversely orientated medullary vascular bundles.

For the structure of the spiny branches of *Carissa*, see Garcin and Lothelier, ll. cc.

Literature: Hansen, Quebracho-Rinde, Berlin, 1880, 24 pp., 3 Tab.—Höhnel, Gerberinden, Berlin, 1880, p. 103 et seq.—Möller, Westind. Buchsholz (*Aspidosperma Vargasii*, DC.), in Dingler, Polytechn. Journ., 238, 1880, pp. 59–62.—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 141.—Garcin, Apocynacées, Thèse, Lyon, 1889, 256 pp., 2 pl.—Lamounette, Liber interne, Ann. sc. nat., sér. 7, t. xi, 1890, pp. 257, 258.—Lothelier, Épines, Thèse, Paris, 1893, p. 18.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Bormann, *Cerbera ovata*, Diss., Erlangen, 1895, 30 pp.—Valeton, *Ochrosia*, Ann. Jardin Buitenzorg, xii, 1895, pp. 226–9.—[Mirabella, Colleteri, Contribuz. Ist. bot. Palermo, ii, 1897, p. 15 et seq.; abstr. in Just, 1897, i, p. 513.]—Pierre, Landolphiées, Bull. Soc. Linn. de Paris, 1898, n. 5, p. 33 et seq. and n. 11, p. 89 et seq.—Grélot, Caoutchoucs et Gutta-Percha, Thèse, Paris, 1899, p. 159 et seq.—Hallier, Kautschuklianen, Jahrb. Hamburg. wiss. Anst., xvii, 3. Beiheft, 1899, Hamburg, 1900, 216 pp.—Leisering, Interxyl. Leptom, Diss., Berlin, 1899, pp. 27 and 37.—Baranetzky, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xii, 1900, pp. 289–92.—Gamper, Angosturarinden, Diss., Zürich, 1900, p. 65.—Payrau, *Strophanthus*, Thèse, Paris, 1900, pp. 37 and 47 et seq.—Thomas, Feuilles sout., Thèse, Paris, 1900.—Molisch, Milchsaft u. Schleimsaft, 1901, pp. 20, 27 and 71.—Petersen, Vedanatomi, 1901, p. 84.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 363 et seq. (*Dyera*, *Cerbera*).—Penzig, Piante acarofile, Malpighia, 1902, p. 450 (*Tabernaemontana*).—Gerhard, Blattanat. v. Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 26, 27 (*Gonioma*).—Quanjer, Anat. Bouw, etc., Natuurkund. Verhandel. Haarlem, iii, 5, 1903 (*Cerbera Odollam*).—Achner, Falsche Chinarinden, Diss., Bern, 1904, p. 64 et seq.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 192, 193.—Areschoug, Trop. vaxt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 26, 27 (*Alstonia*), pp. 29, 30 (*Chilocarpus*).—Haberlandt, Lichtsinnesorgane, 1905, p. 68 and Tab. i.—Kniep, Milchsaft, Flora, 1905, pp. 166, 167.—Mayus, Milchröhr. in den Bl., Beih. z. bot. Centralbl., xviii, Abt. 1, 1905, pp. 279, 280.—Spire, Apocynacées, Thèse, Paris, 1905, 186 pp. (also in Perrot, Travaux, ii).—Piccioli, Legnami, Bull. Siena, 1906, p. 146.—[For further literature, see p. 1169.]

ASCLEPIADEAE (pp. 534–537).

1. Review of the Anatomical Features. To the enumeration of special anatomical features (p. 534) we may add the occurrence of intercellular spaces containing mucilage (*Morrenia odorata*, Lindl.), of secretory cells in the mesophyll (*Solenostemma Arghel*, Heyne), and of long prismatic crystals of oxalate of lime (*Menabea*). Among the anomalies in the structure of the wood we may include the occurrence of islands of soft bast in the wood of the root of *Asclepias syriaca* and *Morrenia brachystephana*, Griseb.

2. Structure of the Leaf. **Stomata** having 4–5 neighbouring cells are found in *Vincetoxicum palustre*, Gray (Kearny), and stomata with 2–5 neighbouring cells in *Solenostemma Arghel* (Tschirch). The mesophyll in *Morrenia brachystephana* contains fat-bodies (Keller).

The prismatic **crystals** mentioned above appear to be of the nature of styloids, and are found in the bast of the root of *Menabea venenata*, Baill., while the tissue of the leaf in this plant contains clustered crystals. The clustered crystals found in the leaf of *Solenostemma Arghel* have the shape of a sphaerite. The non-articulated **laticiferous tubes**, which side by side with intraxylary phloem [1] have recently also been demonstrated in *Conchophyllum*, *Menabea*, and *Morrenia*, penetrate into the mesophyll also in *Periploca graeca* and *Hoya carnosa* (Kniep, Lehmann). Intercellular spaces containing mucilage were observed by Keller in the primary cortex of the terrestrial roots of *Morrenia odorata*; they are situated on the outer side of the endodermis and attain a considerable size. The secretory cells found in the mesophyll in *Solenostemma Arghel* are either rounded or elongated; they have suberized walls and contain a yellow secretion.

3. Structure of the Axis. The wood contains vessels with simple perforations and wood-prosenchyma bearing bordered pits in *Gymnema* also.

[1] The petiole of *Solenostemma Arghel* likewise contains laticiferous tubes and an arc-shaped vascular bundle showing bicollateral structure.

The cork arises in a subepidermal position in *Gymnema*. Chambered crystal-fibres containing clustered crystals are found in the secondary bast in *Gymnema*, and similar elements with solitary crystals in the secondary bast in *Periploca graeca*.

No details are known as to the mode of development of the interxylary phloem in the wood of the root of *Morrenia brachystephana* (see Häntzschel, loc. cit.). The differentiation of the islands of soft bast, observed by Kny in the wood of the root of *Asclepias syriaca*, only takes place at a late stage.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 140.—Kny, Bot. Wandtafeln, vi. Abt., Text, 1884, pp. 237, 238.—Leitgeb, Sphärite, Mitteil. bot. Inst. Graz, Heft 2, 1888, p. 314 et seq.—Keller, Luftwurzeln einiger Dikotylen, Diss., Heidelberg, 1889, pp. 8–12.—Lamounette, Liber interne, Ann. sc. nat., sér. 7, t. xi, 1890, pp. 255–7.—Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 57, 58.—Latour, Séné, These, Montpellier, 1894, p. 25 et seq. (Arghel); see also Tschirch and Oesterle, Anat. Atlas, i, 1895, p. 26 and Tab. 7.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Busch, *Gymnema sylvestre*, etc., Diss., Erlangen, 1895, pp. 14 and 31 et seq.—Karsten, Epiphytenformen, Ann. Jardin Buitenzorg, xii, 1895, p. 154 et seq.—Hantzschel, *Morrenia brachystephana*, Diss., Erlangen, 1895, pp. 12 and 35 et seq.—Lehmann, *Periploca graeca*, Archiv d. Pharm., 235, 1897, p. 159 et seq.—[Mirabella, *Colleteri*, *Contribuz. Ist. bot. Palermo*, ii, 1897, p. 15 et seq.; abstr. in Just, 1897, i, p. 513.]—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 20.—[Tassi, *Hoya carnosa*, Bull. Lab. Orto bot. Siena, 1898, pp. 151–7, 2 tab.; abstr in Just, 1899, ii, p. 245.]—Grélot, Caoutchoucs et Gutta Percha, These, Paris, 1899, p. 163 et seq.—Leisering, Interxylares Leptom, Diss., Berlin, 1899, p. 38.—Kearny, in Contrib. U. S. Nat. Herb., v, n. 5, 1900, p. 303 (*Vincetoxicum*).—Perrot, *Menabea*, Comptes rendus, Paris, cxxxiv, 1902, p. 305; see also Journ. de bot., 1903, pp. 114, 115.—Col, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xx, 1904, pp. 192–4.—Paoli, Eterofillia, Nuovo Giorn. bot. Ital., xi, 1904, p. 219 (*Hemidesmus*).—Süssenguth, Behaarungsverh. der Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 44.—Kniep, Milchröhren, Flora, 1905, pp. 166, 167.—Mayus, Milchrohr. in den Bl., Beih. z. bot. Centralbl., xviii, Abt. 1, 1905, pp. 280, 281.—Sarton, Anat. d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 99, 100 (*Vincetoxicum*).—[Hurner et Perrot, Ginseng, Bull. sc. pharmacol., 1906, p. 665 (*Tylophora*).]—Holtermann, Einfluss des Klimas, etc., 1907, p. 136 (*Hoya*).

LOGANIACEAE (pp. 538–547).

1. Review of the Anatomical Features. Oxalate of lime is deposited in the form of small needles in *Spigelia* also, while in the newly established genus *Crateriphytum*, Scheff. MS. ed. Koorders, as in its nearest ally, the genus *Couthovia*, it occurs in the form of crystal-sand. In the stem of *Gelsemium sempervirens* and '*Spigelia dichotoma*' the intraxylary phloem becomes transformed into medullary vascular bundles, showing inverse orientation. Peculiar extrafloral nectaries taking the form of small pits and provided with a secretory palisade layer are found in *Fagraea*.

2. Structure of the Leaf. A **mucilage-layer** situated beneath the upper epidermis is stated by Morelle to occur also in *Mostuea* '*gabonica*,' *M. Pervilleana*, *Mitrasacme pilosa* and *M. prolifera*; he likewise mentions the occurrence of cells having partially gelatinized walls in the mesophyll of the two species of *Mitrasacme* just named. In *Mitrasacme polymorpha* (*M. cinerascens*) Morelle observed a layer of mucilage, though not so strongly developed, also above the lower epidermis.

The short unicellular **hairs** found in certain species of *Mostuea* and *Mitrasacme* are true papillose-hairs.

The extrafloral **nectaries**, which occur in *Fagraea crassifolia*, Bl., *F. elliptica*, Roxb., *F. imperialis*, Miq., *F. lanceolata*, *F. litoralis*, Bl., *F. monantha*, Miq., *F. obovata*, Wall., and *F. peregrina*, Bl., have been examined especially by Zimmermann (see also Poulsen and Areschoug); they are found on both surfaces of the leaf, at the base of the petiole (here two or more in number) and on the stem below the stipules. They constitute lobed pit-like depressions which vary in shape and open to the exterior by means of a small aperture. The

nectaries situated on the surface of the leaf show a short canal leading into a cavity, which is placed parallel to the surface of the lamina, and from which lateral canals arise; in the case of the nectaries occurring on the petiole and stem the vertical canal is longer, but its branches are less numerous. The wall of these pits is formed by a layer of secretory palisade-cells which have no cuticle, while the layers of cells adjoining the palisade-layer are rich in clustered crystals of oxalate of lime. The starting-point in the development of the nectary is a single epidermal cell, which increases in size, and becomes elongated in a direction at right angles to the surface of the organ. The cells of the epidermis and of the inner tissues bordering on this initial cell likewise undergo elongation and division, and thus give rise to the epithelium. The main cavity of the gland is formed by the separation of the epithelial cells from the epidermal cell, which initiates the formation of the entire glandular mechanism, and may still occasionally be found in the cavity of the mature gland; the lobes are formed solely by the separation of the epithelial cells from one another.

The occurrence of **oxalate of lime** in the form of small needles in *Spigelia* (according to Morelle) and of crystal-sand in *Craterispermum moluccanum*, Scheff. (Koorders) has already been referred to above.

3. Structure of the Axis. On the outer side of the **intraxylary soft bast** in the older parts of the stem and in the rhizomes of *Gelsemium sempervirens* a cambium is formed, which not only produces phloem internally, but at some points also gives rise to wood externally (Bölling). In this way the groups of intraxylary soft bast become transformed into inversely orientated vascular bundles. Such inversely orientated bundles are stated by Morelle to occur also at the margin of the pith in '*Spigelia dichotoma*.'

As regards the structure of the **cortex** we may add that the cork in *Spigelia Sellowiana*, Cham. et Schlecht. arises in the subepidermal layer, and that in certain xerophilous species of *Spigelia* which have reduced leaves (e.g. *S. linarioides* and *S. pulchella*), subepidermal groups of sclerenchyma (visible to the naked eye as ribs) and palisade tissue are developed in the primary cortex (Morelle).

Note. According to Morelle noteworthy features in the structure of the root are the large lacunae in the primary cortex of *Mitrasacme montana* and species of *Mitreola*, and the pericyclic development of the cork in *Mitrasacme cinerascens* (= *M. polymorpha*).

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GENTIANEAE (pp. 548–550).

Our knowledge of the anatomy of the Gentianeae has recently been quite considerably enlarged, especially by Perrot's investigations[1], which deal with the structure of the leaf, stem, and root. The two suborders Gentianoideae and Menyanthoideae differ anatomically not only in the presence (Gentianoideae) or absence (Menyanthoideae) of intraxylary phloem, but also in other anatomical characters. In the Gentianoideae the sieve-tubes both of the outer and intraxylary soft bast (when present, of the interxylary bast as well) almost invariably form small groups of cells with narrow lumina, these groups in a transverse section being approximately of the same size as one of the neighbouring cells of the phloem-parenchyma; in the Menyanthoideae, on the other hand, the sieve-tubes have wide lumina, and are irregularly distributed in the tissue of the soft bast. In the Gentianoideae the formation of the pair of guard-cells is quite generally preceded by two or three divisions in the dermatogen-cell, while in the Menyanthoideae the mother-cell of the guard-cells originates with the appearance of the first division-wall in the dermatogen-cell. Hydathodes, provided with an epithema and water-pores, occur only in the Menyanthoideae, and are wanting in the Gentianoideae. The root in the Gentianoideae has a diarch vascular system, while in the Menyanthoideae the vascular system of the root is polyarch (5–9-arch); secondary division-walls, which are radial or more rarely tangential, occur in the cells of the endodermis only in the Gentianoideae. To the earlier statements on the structure of the wood (see the general diagnosis of the Order) there is nothing to add. The sentence 'a special type of stoma does not occur' must be modified in the sense that distinct subsidiary cells are rarely found. In opposition to the earlier statements it has been shown that oxalate of lime is not absent in this Order. In most of the genera of the Gentianoideae it has been observed as small crystals, taking the shape of prisms, octohedra, needles of varying thickness, or granules, as well as in the form of small clustered crystals. Large numbers of the acicular crystals occasionally lie irregularly scattered in cells with mucilaginous contents, while large quantities of the granular crystals in some cases form a crystal-sand similar to that of the Solanaceae. In the Menyanthoideae oxalate of lime appears to be absent. Typical internal secretory elements do not occur in the Gentianeae, but resinous substances are found in the tissues of the root in species of *Gentiana* and *Sweertia*, isolated tannin-cells or rows of these elements in the Menyanthoideae, and mucilage-cells, as well as gelatinized epidermal cells, in certain species of *Gentiana*. In certain genera of the Gentianoideae, moreover, the epidermis of the ovary contains latex. Recent observations have also demonstrated the rare occurrence of clothing hairs (unicellular or uniseriate hairs, the latter composed of a small number of cells); there are no typical glandular hairs, apart from club-shaped bodies, which consist of a large number of cells and have hitherto been observed only in the axils of the leaves in *Obolaria* and on the leaves in *Bartonia*. To the previous list of special features we may add: the occurrence of islands of soft bast and of vascular bundles in the pith (the latter in species of *Gentiana*); the occurrence of cortical vascular bundles (in certain Menyanthoideae); the anomalous structure of the axis found in the species of

[1] These investigations extend to the following genera (in the serial order of Gilg's system): *Exacum*, *Sebaea*, *Belmontia*, *Enicostemma*, *Faroa*, *Microcala*, *Curtia*, *Neurotheca*, *Geniostemon*, *Cicendia*, *Sabbatia*, *Lapithea*, *Erythraea*, *Chlora*, *Schinziella*, *Canscora*, *Bartonia*, *Obolaria*, *Chironia*, *Orphium* *Crawfurdia*, *Gentiana*, *Ixanthus*. *Pleurogyne*, *Sweertia*, *Halenia*, *Hockinia*, *Lisianthus*, *Eustoma*, *Zygostigma*, *Zonanthus*, *Rusbyanthus*, *Prepusa*, *Senaea*, *Schultesia*, *Coutoubea*, *Purdieanthus*, *Lagenanthus*, *Deianira*, *Lehmanniella*, *Voyriella*, *Leiphaimos*; *Nephrophyllidium*, *Menyanthes*, *Villarsia*, *Limnanthemum*, *Liparophyllum*.

Limnanthemum belonging to the section *Nymphaeanthe* and recalling the structure of a Monocotyledonous stem; the peculiar discoid groups of small cells occurring on the lower side of the leaf in species of *Limnanthemum* and *Villarsia*; and the development of interxylary phloem in the axis in *Chironia*, *Crawfurdia*, *Ixanthus* and *Orphium*, and in the root in many members of the Order.

The following details may be added regarding the STRUCTURE OF THE LEAF in the two suborders. In the Gentianoideae the upper **epidermal cells** are provided with straight or slightly undulated lateral walls, while the lower epidermal cells have strongly curved walls. Papillae are developed in some cases, especially at the margin of the leaf; the cuticle is occasionally striated. The development of the stomata was described above; they are for the most part confined to the lower side of the leaf, although in some cases present on both sides, and are surrounded by 3–4 neighbouring cells. The mesophyll is lacunar and either bifacial or homogeneous in structure. The epidermal cells of the Menyanthoideae have rather straight lateral walls. The stomata, the mode of development of which has likewise been considered above, occur on both sides of the leaf, but are developed only on the upper side in the floating leaves; the guard-cells are surrounded by 4–6 neighbouring cells. The structure of the leaf in this suborder is markedly bifacial, and the spongy tissue is very lacunar. In none of the Gentianeae are the stomata ever strongly depressed or elevated. Large guard-cells are found, for example, in *Gentiana pyrenaica*, L., small ones in *Crawfurdia japonica*, S. et Z. Stomata have also been observed in the typical saprophytes (in *Cotylanthera* by Figdor, in *Obolaria* by Holm and prior to that by Chatin, in *Leiphaimos* and *Voyria* by Svedelius and Porsch). The **veins** of the leaf rarely contain fibrous cells (*Deianira*, *Senaea coerulea*, Taub.), the latter being found in species in which mechanical elements are also developed in the pericycle of the axis. In the Menyanthoideae enlarged terminal tracheids occur at the ends of the veins.

The occurrence and mode of deposition of **oxalate of lime** have already been referred to above[1]. The quantity of the salt excreted varies very considerably. It is met with in the ground tissue and occasionally in the bast and epidermis as well. Mucilage-cells containing acicular crystals have been observed, for example, in *Gentiana cruciata*, L., *G. lutea*, L. and *G. Saponaria*, L., while crystal-sand has been found in species of *Gentiana*, belonging to the section *Chondrophylla*, and, as it seems, also in *Sabbatia*; small clustered crystals occur in species of *Gentiana*, *Lehmanniella* and *Purdieanthus*. There can be little doubt that the crystalline deposits do not possess that degree of systematic importance which Kusnezow attributes to the occurrence of oxalate of lime in the mesophyll in the genus *Gentiana*; according to him oxalate of lime is present in all the sections of the subgenus *Eugentiana* with the exception of the section *Cyclostigma*, while emphasis is laid on its absence in the section just named and in the subgenus *Gentianella*.

Perrot's statements as to the exact nature of the **mucilage-cells** are not always quite clearly presented; according to him, moreover, the demonstration of these elements in herbarium-material was attended with difficulty. Mucilage is found mainly in the leaf and in the root. As regards the former, Perrot, in the first place, records slightly gelatinized cells in the mesophyll in *Belmontia cordata*, E. Mey., and leaves containing mucilage in *Canscora*, *Gentiana Parryi*, Engelm. and *G. triflora*, Pallas (sect. *Pneumonanthe*), and species of *Gentiana*

[1] Perrot and other authorities have demonstrated oxalate of lime in species of the following genera: *Exacum*, *Sebaea*, *Belmontia*, *Enicostemma*, *Faroa*, *Microcala*, *Neurotheca*, *Sabbatia*, *Erythraea*, *Chlora*, *Schinziella*, *Crawfurdia*, *Gentiana*, *Ixanthus*, *Sweertia*, *Halenia*, *Rusbyanthus*, *Schultesia*, *Purdieanthus*, *Lagenanthus*, *Deianira*, *Lehmanniella*. Perrot distinctly mentions the absence of oxalate of lime in *Coutoubea*, *Prepusa*, *Senaea* and in the Menyanthoideae.

belonging to the section *Stenogyne*. Epidermal cells of the leaf having mucilaginous inner walls occur in *Gentiana bavarica*, L., *G. excisa*, Presl and *G. verna*, L., while in *G. pyrenaica*, L., a complete layer of mucilage, formed by the gelatinization of the inner walls of the epidermal cells and the walls of the adjoining mesophyll-cells, is found beneath the upper epidermis. A similar layer of mucilage is present also beneath the epidermis of the stem in *Gentiana saxosa*, Forst. In the species of *Gentiana* belonging to the section *Chondrophylla*, which are endemic in the region of the Himalayas and on the high mountains of Western China, the tissue of the leaf is gelatinized to quite an exceptional extent. The process of gelatinization in this case only affects the middle portion of the lamina and does not extend to the margin of the leaf, which has a horny appearance characteristic of these species; the extent of gelatinization is such, that transverse sections mounted in water as a rule show nothing but mucilage, the cuticle of the upper and lower epidermis, and the vessels. The thick roots of the species of *Sweertia* belonging to the section *Ophelia* also contain a little mucilage, while the cork-like tissue found on the surface of the roots in *Nephrophyllidium crista-galli*, Gilg, includes a mucilaginous substance.

The **cartilaginous margins** above mentioned as characteristic of the leaves in the species of *Gentiana*, sect. *Chondrophylla*, vary in breadth, and either contain a tissue with cartilaginous walls (*G. quadrifaria*, Bl.) or consist merely of the thick-walled upper and lower epidermis (*G. albescens*, Franch.). Thick cell-walls having the same cartilaginous texture are met with also in the cortical tissue of the stem (primary cortex and bast) in *G. papillosa*, Franch., and other species belonging to the same group.

Perrot mentions the occurrence of (*a*) **resinous substances** in the cortical tissue of the root in *Gentiana lutea*, L. and *G. purpurea*, L., as well as in *Sweertia Chirata*, Ham., *S. Hookeri*, Clarke, *S. Kingii*, Hook. and *S. multicaulis*, Don; (*b*) tannin-cells in the rhizome of *Nephrophyllidium* and *Villarsia*; and (*c*) latex in the epidermal cells (which are here elongated at right angles to the surface) of the ovary of *Canscora*, *Chironia*, *Chlora*, *Erythraea*, *Lisianthus*, *Schultesia* and *Sweertia*, and to these we may, on Baillon's authority, add *Sabbatia* [1].

The branched spicular cells, which are differentiated as **internal hairs** (p. 548), do not occur in the root. The tissue of the latter contains only unbranched sclerotic cells, and these are not abundant. Perrot observed rather long uni- or bicellular **trichomes** also in a few species of *Sweertia*, whose names are not mentioned. The unicellular hairs in this case are either elongated trichomes with a bulbous swelling at their base, or are connected with papillae by means of transitional forms. Papillae, varying in shape from conical to elongated-cylindrical and commonly striated, are present on the epidermis of the stem or leaf (here especially on the margin), or on both in many Gentianoideae, e.g. in species of *Curtia*, *Exacum*, *Gentiana* (species belonging to various sections, such as *Pneumonanthe*, *Stenogyne*, *Frigida*, *Isomeria*, *Chondrophylla*, *Andicola* and *Amarella*), *Halenia*, *Hockinia*, *Ixanthus*, *Orphium*, *Purdieanthus*, and *Sweertia*. Another noteworthy feature lies in the occurrence of glandular shaggy hairs in the axils of the sepals (bracts according to Baillon's interpretation) and foliage-leaves in *Obolaria virginica*, L. (Baillon, Knoblauch), and on the leaves in *Bartonia verna*, Mühl. and *B. lanceolata*, Small (Holm). Their structure is similar to that of the glands which are situated in the depressions between the corolla-lobes, and are figured by Holm. In shape they recall

[1] We may notice here that according to Figdor the starch-grains in the stem and root of *Cotylanthera* become coloured red by Iodine solution, and consequently consist of amylodextrin. Starch-grains showing the same reaction had previously been observed by Russow and A. Meyer in *Gentiana lutea* and *Sweertia perennis*.

the well-known glandular shaggy hairs found in the Rubiaceae, &c., but differ from them in the absence of a vascular bundle and in the fact that the epidermis of the body of the gland, which is composed of numerous cells, is not developed as a layer of palisade-cells. Glandular bodies of this type are probably more widely distributed in the Order. **Hydathodes**, as already stated above, while completely absent in the Gentianoideae, are characteristic of the Menyanthoideae. They consist of the termination of a vein, associated with an epithema including a varying number of spirally thickened cells, and of a small group of water-pores; they are found either on the leaf-teeth or on the margin of edentate leaves, and occur either on the upper or lower surface. The peculiar groups of cells previously mentioned as present in the lower epidermis of the leaf occur in *Limnanthemum lacunosum*, Griseb., *L. Humboldtianum*, Griseb. and *L. nymphaeoides*, Link, as well as in *Villarsia parnassifolia*, R. Br.; they constitute disc-shaped areas, composed of cells which differ from the ordinary epidermal cells (which contain a violet cell-sap) in having a smaller polygonal outline in surface-view and tanniniferous contents. They are the cause of the shagreen-like appearance of the lower surface of the leaf, which is noticeable even to the naked eye.

In amplification of the earlier statements on the structure of the **petiole** we may firstly mention, that in the Gentianoideae it contains an arc of wood and bast showing bicollateral structure, two small lateral bundles being occasionally cut off from the ends of this arc. Among the Menyanthoideae the vascular system of the petiole consists of a more or less open arc of isolated vascular bundles supported by fibrous cells in *Menyanthes* and *Nephrophyllidium*, while in the species of *Limnanthemum* belonging to the section *Nymphaeanthe* the bundles show a scattered arrangement like that in the stem of a Monocotyledon, and in *Villarsia lasiosperma*, F. v. M. the bundles are isolated and arranged in two concentric arcs with their xylem-groups directed upwards.

With reference to the distribution of bicollateral vascular bundles in the Gentianoideae we may note that Figdor and Perrot have recently demonstrated the occurrence of **intraxylary phloem** also in those genera, which were not investigated by Gilg (viz. *Cotylanthera*, *Voyriella* and *Lagenanthus*); moreover the previous mention of '*Voyria*' as an exception (see footnote 1 on p. 548) may be cancelled, since according to Gilg the species of *Voyria* having concentric vascular bundles in their axes (referred to on p. 550) belong to the genus *Leiphaimos*. But even these species of *Leiphaimos*, in which the vascular bundles are concentric with central xylem, as well as *Leiphaimos parasitica*, Cham. et Schlecht., in which the bundles have strands of phloem only on their inner side, do not constitute real exceptions to the rule; for we must bear in mind that the concentric vascular bundles can easily be derived from bicollateral ones, such a derivation being justified from the biological point of view, while the case of *Leiphaimos parasitica* finds a certain amount of analogy in the reduction of the outer soft bast, occurring also in other Gentianoideae with a bicollateral vascular system, although the reduction in these cases is not so far-going. Groups of soft bast situated at a greater depth in the body of the pith are found in *Cotylanthera tenuis*, Bl., *Erythraea Centaurium*, Pers., *Gentiana cruciata*, L. and other species of the section *Aptera*, *G. excisa*, Presl, *Obolaria virginica*, L. and in species of *Bartonia*. In certain species of *Gentiana*, moreover, some of the phloem-strands situated at the margin or in the interior of the pith also include vessels, and thus become changed into medullary vascular bundles, as is so frequently the case in the Melastomaceae; this feature has been observed in *Gentiana Andrewsii*, Griseb., *G. bavarica*, L., *G. Burseri*, Lapeyr., *G. Delavayi*, Franch., *G. germanica*, Willd., *G. lutea*, L., *G. Pneumonanthe*, L., *G. punctata*, L., *G. purpurea*, L., *G. stylophora*, Clarke. Fibrous cells are rarely (*Deianira nervosa*, Cham. et Schlecht., *Lisianthus*

nigrescens, Cham. et Schlecht.) found accompanying the inner soft bast; in some cases the groups of intraxylary soft bast appear to be embedded in the ring of wood owing to sclerosis of the neighbouring cells (*Exacum tetragonum*, Roxb., *Erythraea Centaurium*, Pers.), or the internal phloem may be supported by a ring of sclerosed medullary cells, which extends up to the central lacuna of the pith (*Eustoma*).

We may next turn our attention to the structure of the **wood**. Most of the Gentianeae (i.e. apart from a few semi-saprophytic or holo-saprophytic Gentianoideae and the Menyanthoideae) have a continuous ring of wood, the inner part of which is generally (with the exception of those species, in which the cambium produces a considerable increment of secondary wood) rich in vessels, while the outer part consists of mechanical fibrous tissue. Perrot records uniseriate medullary rays also in species of *Rusbyanthus*, *Senaea* and *Zonanthus*, and Figdor mentions the occurrence of reticulate perforations in the vessels in *Cotylanthera tenuis*, Bl. For the structure of the wood in the saprophytic species and in the Menyanthoideae, see under the discussion of the vascular system in the stem of these forms.

In those members of the Order which are provided with a ring of wood the **outer bast** is reduced (especially in the parts of the axis belonging to the floral region) to a few layers of parenchymatous cells, surrounding the small groups of sieve-tubes. The latter occasionally constitute the entire outer bast, and in this case appear to be embedded in niches in the xylem-ring, which extends right up to the endodermis (species of *Chironia*, *Chlora*, *Geniostemon*, *Gentiana*, *Neurotheca*, *Schultesia*, *Sweertia*). Among the Gentianoideae such small groups of sieve-tubes with narrow lumina are absent only in *Rusbyanthus*, which has isolated sieve-tubes (Perrot).

The **primary cortex** in the Gentianoideae is more or less lacunar, and occasionally contains mucilage; in other cases it is compressed, and consists of a tissue resembling horn-bast. In the Menyanthoideae large air-canals interrupted by transverse diaphragms, are present both in the stem and rhizome. The stems of the Gentianoideae are very commonly provided with four ribs or wings, which are either formed solely by two epidermal layers (*Sebaea ovata*, R. Br.) or contain collenchymatous tissue (*S. albens*, R.Br., *S. aurea*, R.Br.). There is often a distinct endodermis, provided with Caspary's dots; the endodermal cells rarely (*Crawfurdia*, *Gentiana pyrenaica*, L.) show secondary radial walls, and when present they occur only in small numbers (1 or 2). The pericycle generally consists of thin-walled tissue, and often comprises only a single layer of cells. According to Perrot a small number of fibrous or sclerenchymatous cells are found in the pericycle in species of *Chironia*, *Deianira*, *Lagenanthus*, *Lehmanniella*, *Lisianthus*, *Prepusa*, *Purdieanthus*, *Rusbyanthus*, *Senaea* and *Zonanthus*, while in some of the saprophytic Gentianoideae and certain Menyanthoideae (see below) the presence of strongly developed bundles of fibres or of a sclerenchymatous ring in the pericycle compensates for the absence of mechanical tissue in the wood.

Interxylary phloem is developed in the axis in numerous species of *Chironia*, in *Crawfurdia volubilis*, Gilg and *C. japonica*, S. et Z. (here according to Perrot), *Ixanthus viscosus*, Griseb. and *Orphium frutescens*, E. Mey. Islands of soft bast are much more widely distributed in the wood of the root. According to Perrot's investigations they are found in species of *Canscora*, *Chironia*, *Chlora* (*C. perfoliata*, L. and *C. serotina*, Koch), *Cicendia* (*C. pusilla*, Griseb.), *Crawfurdia*, *Erythraea* (species of the sections *Euerythraea*, *Trichostylus* and *Spicaria*), *Eustoma*, *Exacum*, *Gentiana* (species of the sections *Coelanthe* and *Pneumonanthe*, *Gentiana crinita*, Fröl., belonging to the section *Crossopetalum*), *Halenia*, *Sabbatia*, *Sweertia* (species of the sections *Ophelia* and *Eusweertia*, which have small tuberous roots). The recent observations have shown that

the islands of interxylary soft bast no doubt in all cases arise from groups of unlignified tissue, which are produced internally by the cambium and in which sieve-tubes are secondarily differentiated. The islands of soft bast found in the wood of the axis are invariably of small size and are more abundant in the lower part of the stem as a result of its growth in thickness than in the upper part. In those roots in which the wood contains lignified mechanical tissue in addition to the vessels, the islands of interxylary soft bast for the most part form slightly larger groups, consisting of thin-walled cells and sieve-tubes, near the centre of the root (e.g. in the species of *Chlora, Cicendia, Erythraea, Eustoma, Exacum, Halenia, Sabbatia*); more rarely the phloem-islands are distributed throughout the entire mass of the wood, being in this case arranged in more or less irregular rings (*Chironia*). In those roots in which the body of the wood is unlignified (e.g. in *Gentiana lutea*, &c.) numerous small islands of soft bast are found irregularly distributed throughout its entire mass. It may still be noted that in the roots of certain Gentianoideae (*Deianira, Gentiana campestris*, L.) in which the xylem-mass is strongly lignified, groups of unlignified tissue, which do not however include any sieve-tubes, occasionally occur near the centre of the wood; these must not be confounded with interxylary phloem.

In the herbaceous Gentianoideae the **pith** as a rule becomes fistular when the period of flowering is over. Under these circumstances the medullary strands of mestome (see above) likewise disappear. In *Sabbatia* a complete border of corky tissue develops at the periphery of the central air-canal. Isolated sclerenchymatous cells are of rare occurrence (*Gentiana Pneumonanthe*, L.) in the pith, but the periphery of the pith is occasionally sclerosed. In *Lehmanniella acuminata*, Gilg and *Senaea coerulea*, Taub. the entire pith is sclerosed. The pith of the Menyanthoideae is traversed by large air-canals like those found in the primary cortex in this group.

The following details may be mentioned regarding the fibrovascular system of the **axis in the Menyanthoideae**; the latter shows anomalous structure only in the species of *Limnanthemum* belonging to the section *Nymphaeanthe*. As a general rule the vascular bundles are isolated. In *Nephrophyllidium crista-galli*, Gilg the isolated bundles found in the axis of the inflorescence are inserted in a ring of pericyclic sclerenchyma. A transverse section through the rhizome or the axis of the inflorescence in *Menyanthes trifoliata*, L. shows isolated vascular bundles, which are supported both on their inner and outer sides by strongly developed strands of fibres. The isolated bundles in the rhizome and axis of the inflorescence of *Villarsia* have arcs of bast-fibres or a ring of sclerenchyma on their outer side. In *Limnanthemum nymphaeoides*, Link, the only species of the section *Waldschmidtia*, the rhizome contains an almost complete ring of wood and bast without sclerenchyma, while the peduncle and the axis of the shoot exhibit a ring of isolated vascular bundles surrounded by a starch-sheath. On the other hand, in the species of *Limnanthemum* belonging to the section *Nymphaeanthe* the isolated vascular bundles, as already stated in the earlier part of this work (p. 550), show an irregular scattered arrangement in a transverse section through the axis, resembling that of a Monocotyledon, although the bundles are open. The centre of the stem in these species is almost invariably occupied by a large 'double vascular bundle,' formed by two bundles with their xylem-groups directed towards one another; this large bundle may be said to constitute the stele, the remaining bundles being regarded as cortical. The mode of arrangement of the vascular bundles in the axis of the species of *Limnanthemum* belonging to the section *Nymphaeanthe* is doubtless an advanced adaptation to life in water. In the vascular bundles of the Menyanthoideae a relatively large group of unlignified parenchyma is generally situated on the inner side of the xylem; this parenchyma

does not include any primary vessels, and may be looked upon as being homologous with the internal soft bast. Schizogenous intercellular canals occasionally (*Menyanthes trifoliata*) arise in this tissue, and in some cases this is followed by lignification of the walls of the adjoining cells.

Cortical vascular bundles (see p. 550) are found also in the stem of *Limnanthemum nymphaeoides* and in the rhizome of *Villarsia exaltata*, F. v. M. In the latter species the cortical bundles are inversely orientated and inserted in the ring of pericyclic sclerenchyma, as it were on the back of the normal vascular bundles.

The previous account (p. 550) of the structure of the **stem in the saprophytic Gentianoideae**, apart from the statement concerning the bicollateral vascular system of *Voyria rosea*, Aubl. (on Gilg's authority), dealt exclusively with the genus *Leiphaimos*, since, according to Gilg, the species investigated by Johow and formerly referred to *Voyria* belong to *Leiphaimos*. We will now once more summarize the features presented by the structure of the axis in the saprophytic genera, taking the results of recent work into consideration. Those cases in which there is no strengthening ring in the stem may first be considered. The vascular system then consists either solely of four concentric vascular bundles with a few vessels in the middle and a few peripheral phloem-bundles (*Leiphaimos azurea*, Gilg, *L. flavescens*, Gilg and *L. tenella*, Miq.), or of an almost annular and closed ring of vascular bundles showing bicollateral structure and not containing any mechanical tissue (*Cotylanthera tenuis*, Bl.). In other cases a strengthening ring is present, and here we may likewise distinguish two modifications, according as the strengthening ring is developed as a ring of pericyclic sclerenchyma or as the xylem-ring of the fibrovascular sytem. A pericyclic strengthening ring is found in *Leiphaimos aphylla*, Gilg, *L. parasitica*, Cham. et Schlecht. and *L. trinitensis*, Gilg; in two of these species (*L. aphylla*, *L. trinitensis*) six concentric vascular bundles with central xylem are apposed to the inner side of this ring, while in the third species (*L. parasitica*) there are six vascular bundles, in which phloem-groups are developed only on the side facing the pith, while the xylem-groups are embedded in the strengthening ring. On the other hand, *Voyria coerulea*, Aubl., *Voyriella parviflora*, Miq. and the semi-saprophytic species *Obolaria virginica*, L., have a bicollateral vascular system, the xylem of which constitutes the strengthening ring. *Voyria rosea*, Aubl., which according to Gilg has four bicollateral vascular bundles 'not actually in connexion with one another, although very close together,' should probably be classed with *Cotylanthera*. Among the species of the semi-saprophytic genus *Bartonia*, *B. lanceolata*, Small more or less conforms to the type of stem-structure found in *Obolaria virginica*; in *B. verna*, Mühl. neither the wood nor the pericycle contain mechanical tissue, while the bundles in the higher internodes of the stem show an irregular differentiation, since one finds both collateral and bicollateral vascular bundles as well as mere phloem- or xylem-groups on the inner side of the endodermis (for details, see Holm, loc. cit.).

In dealing with the structure of the **root** in the Gentianeae an important point to notice is that the radial vascular system in the Gentianoideae consists of two xylem- and two phloem-groups, while in the Menyanthoideae the number of groups is larger (5–9). In many of the Gentianoideae the structure of the endodermis is very characteristic. Its cells, which are provided with Caspary's dots on their radial walls, in the first place grow strongly in the tangential direction; this is followed by the appearance of secondary radial division-walls in each cell in numbers, which vary from 2 to 20 according to the species, and even show variation within certain limits in one and the same species; tangential division-walls are more rarely found side by side with the radial ones. Perrot mentions the occurrence of radial divisions in the endodermal cells in species of *Crawfurdia*, *Erythraea*, *Exacum*, *Gentiana* (species

of the sections *Coelanthe, Pneumonanthe, Stenogyne, Frigida, Aptera, Isomeria, Chondrophylla, Thylacites, Cyclostigma, Andicola* and *Amarella*), *Pleurogyne* and *Sebaea*, while endodermal cells with radial and tangential division-walls are recorded by the same authority in *Gentiana ternifolia*, Franch., and by Holm in *Obolaria virginica*, L. In *Sweertia connata*, F. v. M., *S. perennis*, L. and other species of *Sweertia* belonging to the section *Eusweertia* there are two endodermal zones, in which radial division-walls are found, the two zones being separated from one another by a few parenchymatous layers. Perrot expressly mentions the occurrence of undivided endodermal cells in *Belmontia*, *Curtia*, *Microcala* and *Sabbatia*; in *Chironia* some of the endodermal cells have no secondary radial walls, while others have a few. Cell-divisions, similar to those observed in the endodermis, occasionally (*Gentiana ciliata* according to Vuillemin) occur also in the outermost cell-layer of the primary cortex. In the Menyanthoideae only simple endodermal cells are found. Development of cork in the root has been observed only in *Gentiana lutea, G. purpurea*, &c., where it takes place in the pericycle. In the Gentianoideae the primary cortex of the root mostly decays and the part external to the endodermis becomes detached. In those cases in which the endodermis is thrown off as well the cell-layers of the pericycle become successively suberized. In *Halenia elliptica*, Don the primary cortex of the tap-root contains sclerosed cells. Bast-fibres or other types of sclerenchymatous elements are sometimes found also in the pericycle (species of *Chironia, Enicostemma, Exacum*). The structure of the wood and the occurrence of islands of interxylary soft bast have already been discussed above. A pith is present in the root in the Menyanthoideae and occasionally also in the Gentianoideae. As regards the saprophytic forms we may add that distinct root-hairs are absent in *Obolaria* and *Bartonia* according to Holm, and in *Leiphaimos* according to Johow and Svedelius, whilst in *Cotylanthera*, according to Figdor, root-hairs of a reduced type are found. According to Stahl, moreover, root-hairs do not appear to be developed either in the smaller species of *Gentiana* (e.g. *G. asclepiadea, G. ciliata, G. cruciata*, &c.), whilst a mycorrhiza is present not only in the saprophytic species, but is widely distributed also among the green Gentianoideae (species of *Chlora, Erythraea, Gentiana*).

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 139 et seq.—Haberlandt, Spaltöffn. d. Schwimmpfl., Flora, 1887, p. 103.—Baillon, in Bull. Soc. Linn. de Paris, 1, 1888, p. 756; see also Hist. d. pl., x, 1891, p. 124.—Johow, Humuspfl., in Pringsheim Jahrb., xx, 1889, p. 475 et seq.—Solereder, Loganiaceae, in Natürl. Pflanzenfam., iv. Teil, Abt. 2, 1892, p. 27, footnote.—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.—A. Meyer, Stärkekörner, 1895, p. 80.—Kusnezow, *Gentiana*, in Natürl. Pflanzenfam., iv. Teil, Abt. 2, 1895, p. 81 et seq.—Figdor, *Cotylanthera*, Ann. Jardin bot. Buitenzorg, xiv, 1897, pp. 213–40, especially p. 222 et seq. and Tab. xvi.—Holm, *Obolaria*, Ann. of Bot., xi, 1897, pp. 369–83 and pl. xix; see also Proceed. Americ. Assoc., xliv, Salem, 1896, p. 189.—Perrot, Tissu extralibérien, etc., Comptes rendus, Paris, 1897, p. 1115 et seq.; and Tissu conducteur surnum., Journ. de bot., 1897, p. 374 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, pp. 19, 20.—Wollenweber, Anat. der Schwimmbl., Diss., Freiburg i. Br., 1897, pp. 19–20.—Perrot, Anat. comp. des Gentian., Ann. sc. nat., sér. 8, t. vii, 1898, pp. 105–292 and pl. i–ix; also Thèse, Paris; see also Assoc. franç. Nantes, 1898.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 33–5.—Stahl, Sinn der Mykorrhizenbild., in Pringsheim Jahrb., xxxiv, 1900, p. 586 et seq.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 42, 43 (*Ixanthus*).—Svedelius, Saprophyt. Gentian., Bih. Svenska Vet.-Akad. Handlingar, xxviii, Afd. iii, n. 4, 1902, 16 pp.—Vuillemin, Bois interméd., Comptes rendus, Paris, cxxxv, 1902, pp. 1367–9; id., *Gentiana ciliata*, Bull. Soc. bot. de France, 1902, pp. 274–80, and Bull. Soc. Sc. de Nancy, iii, 1902, pp. 158–74 and pl.—[Porsch, Spaltöffnungsapp. submers. Pflanzenteile, Sitz. Ber. Wiener Akad., cxii, Abt. 1, 1903, p. 124 (*Menyanthes*).]—Schoch, *Chironia*, Beih. z. bot. Centralbl., xiv, 1903, pp. 183, 184.—Schoute, Stelärtheorie, 1903, p. 125.—[Aug. Vogl, Kalkoxalat bei Gentian., Zeitschr. Österreich. Apothekerver. Wien, 1903, n. 6 and 7; abstr. in Bot. Centralbl., xcii, p. 432.]—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 188–92, etc.—Süssenguth, Behaarungsverh., etc., Diss., Würzburg, 1904, p. 44.—Theorin, Växttrichom., Arkiv för Bot., iii, n. 5, 1904, p. 27.—Gürtler, Interzellulare Haarbild., Diss., Berlin, 1905, pp. 30–40.—Porsch, Spaltöffnungstypus, Jena, 1905, pp. 80–3.—Holm, *Bartonia*, Ann. of Bot., xx, 1906, pp. 441–8 and pl. xxxiii, xxxiv.—[Pilger, in Natürl. Pflanzenfam., Erg.-Heft ii, 1908, p. 292.]

POLEMONIACEAE (pp. 550–552).

The paragraph dealing with the essential ANATOMICAL FEATURES of the Polemoniaceae requires the following additions or alterations. Oxalate of lime, though not abundant, does occur in the Polemoniaceae, being found for the most part in the form of small acicular, prismatic, or otherwise shaped crystals (species of *Bonplandia*, *Collomia*, *Gilia*); typical small clustered crystals have also been observed in *Bonplandia*. True cystoliths are absent, the statements in the literature referring to their occurrence being incorrect. On the other hand, cystolith-like protuberances are found in the cells of the epidermis and of the hairs. The complete absence of gelatinized epidermal cells in the leaf is remarkable in view of the xerophilous character of many Polemoniaceae. The hairy covering consists of unicellular (these, however, never constituting the only forms of hairs) and uniseriate clothing hairs, as well as of glandular hairs. Specially noteworthy forms of clothing hairs are as follows: the uniseriate trichomes of *Gilia congesta*, Hook., which are fused in pairs at the base; the uniseriate hairs of certain species of *Phlox* and *Gilia*, which show a tendency to branch; the bicellular whip-hairs of *Gilia densifolia*, Benth., and other species, which are provided with a short basal cell and a long terminal cell; and the urn-shaped trichomes of *Gilia pinnatifida*, Nutt.

The STRUCTURE OF THE LEAF has repeatedly been examined by Wölfel and especially by Hüller; the subsequent description is based on Hüller's statements. In those species which have narrow leaves the **epidermal cells** are generally elongated in the direction of the median vein and occasionally appear almost prosenchymatous in surface-view; in the species with broader leaves the lateral walls of the epidermal cells are often undulated (occasionally showing angular bends and jagged), more rarely straight. The cuticle is smooth or finely striated, or it may be granular or verrucose; in many species of *Collomia*, *Gilia* and *Phlox* the part of the outer wall lying on the inner side of the cuticle is strongly thickened and capable of swelling, and has a gelatinized appearance. But gelatinization of the epidermis does not occur. Isolated epidermal cells showing papillose differentiation are not uncommonly found on the margin and near the apex of the leaf, and in some cases a silicified protuberance resembling a cystolith is associated with these papillae (species of *Bonplandia*, *Collomia*, *Gilia*, *Loeselia* and *Phlox*). Papillae are never differentiated on all or almost all the epidermal cells on the surface of the leaf. The **stomata** are found on both sides of the leaf, especially in the species with narrow leaves; only in a few cases are they confined to the lower surface. Special mention may be made of the arrangement of the stomata in *Phlox Hoodii*, Richards.; this species has narrow leaves which are somewhat adpressed to the stem and cover one another in imbricate fashion, the stomata which occur on both surfaces being almost confined to the base of the leaf, which is protected by means of hairs. In those species, which have narrow leaves, the pairs of guard-cells are arranged approximately parallel to the median vein; a really irregular arrangement of the stomata is altogether rare in this Order. There are no subsidiary cells, the stomata developing according to the Ranunculaceous type (*Cobaea*, *Gilia*, *Phlox*, *Polemonium*). The pairs of guard-cells for the most part lie on a level with the epidermis, and deeply sunk stomata do not occur. The **mesophyll** is bifacial or centric. The spongy tissue only rarely (*Phlox amoena*, Sims.) shows very large intercellular spaces. In *Phlox longifolia*, Nutt. and a few species of *Gilia* (e.g. *G. Parishii*, Pet.) an aqueous tissue composed of large cells devoid of chlorophyll is found in the middle of the mesophyll; this tissue envelops the veins of the leaf and sometimes even surrounds the principal vein. **Hypoderm** occurs only at the

margin of the leaf and above the median vein ; as a rule it consists of fibrous cells, provided with strongly thickened cellulose-walls, which are capable of swelling. The vascular bundles of the **veins** are commonly accompanied by sclerenchyma, which is apposed to the xylem- and phloem-groups. In some species a group of sclerenchymatous fibres is found also in the xylem of the larger veins, these fibres adjoining the tracheae and being in contact with the soft bast. In this connexion we may mention a few anomalous cases concerning the appearance of the vascular bundle of the median vein, as seen in transverse section ; these anomalies have been demonstrated in the upper two-thirds of the leaf in *Phlox Drummondii*, Hook. and a few species of *Gilia*. In some cases the group of sclerenchyma above mentioned enters into connexion with the sclerenchymatous layer below the soft bast by means of a bridge of sclerenchyma, and in this way the strip of soft bast becomes divided into two groups, as in the vascular bundles of certain Palms. In other cases vascular bundles have been observed, consisting for the most part of sclerenchyma, a group of annular and spiral tracheae being apposed to the upper side of the latter, while two to four small phloem-bundles accompanied by spiral and annular tracheae are situated at its sides. Parenchymatous sheaths consisting of large cells have been observed in certain species of all the genera except *Bonplandia*. In some cases they are differentiated like an endodermis (cells suberized in *Phlox amoena*, Sims. and *P. Drummondii*, Hook. ; cells thickened in the shape of a horseshoe in *Gilia pungens*, Benth.).

The following facts may be mentioned regarding the **hairy covering**. The clothing hairs, apart from the more or less hair-like papillae above discussed, include only uniseriate trichomes. Unicellular clothing hairs have not been recorded as the only form of trichome in any member of the Order. The uniseriate hairs vary in length, being composed of long or short cells ; the following types are found :—short conical hairs, consisting of a small number of cells and mostly placed obliquely to the surface with their apex pointing towards the tip of the leaf ; stiff hairs, which are longer and are either straight or curved like a sabre ; and woolly hairs, bent in a vermicular manner. The walls of the hairs vary in thickness ; they are never calcified, but occasionally slightly silicified. Regarding the special forms of clothing hairs above referred to we may add the following details. In *Phlox maculata*, L. only one or two of the 3–5 cells composing the trichomes bear short protrusions, while in *Gilia dianthoides*, Endl. each cell of the multicellular trichome has such a protrusion, so that hairs are formed which have a kind of sympodial structure. The urn-shaped trichomes of *Gilia pinnatifida*, Nutt. in the simplest case consist of two bluntly conical cells having a common basal surface, but a cylindrical cell which is slightly narrowed in the middle of its length is sometimes inserted between the former ; in the three-celled hairs, moreover, the lowest cell is occasionally also cylindrical. It remains to mention the uniseriate trichomes of *Gilia Larseni*, Gray, which are composed of barrel-shaped cells, and the uniseriate hairs of *G. floccosa*, Gray, in which the longitudinal walls are provided with numerous small papillose protrusions. The glandular hairs show the same type of structure as the clothing hairs ; in some cases (species of *Gilia*) transitional forms between the two kinds of hairs are found at the base of the leaf. The variations in structure exhibited by the glandular hairs concern the length of the stalk and the number of cells composing it, and especially the nature of the head. In some of the hairs the head is unicellular and spherical, ellipsoidal or clavate in shape ; glandular hairs with heads of this type are the only forms of external glands found in *Bonplandia*, *Cantua* and *Cobaea* (in the last of these genera they constitute the only type of hair), but they also occur side by side with glandular hairs having multicellular heads in the remaining five genera of the Polemoniaceae. Glandular hairs with spherical

heads, divided into 2–8 cells by one or more radially arranged vertical walls, are found in many species of *Collomia, Gilia, Loeselia, Phlox* and *Polemonium*. Lastly, in certain species of *Collomia, Gilia* and *Phlox* glandular hairs are found in which the heads are obconical, or more rarely discoid or almost spherical, and are divided in the first place by horizontal walls into 2–4 tiers, which undergo further division by vertical walls.

Oxalate of lime is found in certain species of *Collomia* and *Gilia* in the form of the small crystalline bodies above mentioned, the latter occurring in the mesophyll and occasionally in the epidermis and trichomes as well. In *Gilia atractyloides*, Steud. these small crystals are united to form structures resembling clustered crystals. Distinct clustered crystals of small size occur in *Bonplandia geminiflora*, Cav., lying singly in each cell of the palisade tissue; in addition to them the small crystals are likewise present in the mesophyll of *Bonplandia*. Greenish and Morelle's statement to the effect that typical calcified cystoliths occur in '*Phlox carolina*' is incorrect according to Holm, Hüller and Stockberger; the material, which Greenish and Morelle used in their investigations under the name of '*Phlox carolina*,' does not belong to a member of the Polemoniaceae, but to one of the Acanthaceae (according to Holm, *Ruellia ciliosa*, Pursh).

For the STRUCTURE OF THE STEM, see also the detailed statements by Wölfel, loc. cit. According to Wölfel the vessels have a small number of scalariform perforations (with 1–10 bars) side by side with the simple perforations also in *Polemonium* and *Gilia*.

Literature: Wölfel. Vergl. Anat. d. Polemon., Diss., Heidelberg, 1901, 62 pp., 2 Tab.—Theorin, Vaxttrichom., Arkiv for Bot., 1, 1903, p. 159.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 113.—Morelle, Histol. comp. des Gelsémiées et Spigeliées, Thèse, Paris, 1904, pp. 144–7; also in Perrot, Travaux, ii, 1905.—[Stockberger, in Proceed. Americ. pharm. Assoc., liii, 1905, p. 324.]—Holm, Root-structure of *Spigelia marilandica, Phlox ovata*, etc., Americ. Journ. of pharm., 1906, p. 553 et seq.; and Internal structure of the stem and leaf of *Ruellia ciliosa, Phlox ovata*, etc., loc. cit., 1907, p. 51 et seq.—Hüller, Beitr. z. vergl. Anat. d. Polemon., Diss., Erlangen, 1907, 75 pp., 1 Tab., sep. copy from Beih. z. bot. Centralbl.—Brand, Polemoniaceae, in Pflanzenreich, Heft 27, 1907, pp. 3, 4.

HYDROPHYLLACEAE (pp. 552–554).

Literature: [Ritter, *Eriodictyon glutinosum*, Americ. Journ. Pharm., 1895, p. 565 et seq.]—Minden, Wassersez. Org., Bibl. bot., Heft 46, 1899, pp. 26 and 38.—Theorin, Vaxttrichom., Arkiv för Bot., iii, n. 5, 1904, p. 26, and iv, n. 18, 1905, pp. 16, 17.

BORAGINEAE (pp. 554–561).

2. STRUCTURE OF THE LEAF. **Epidermal cells** which have jagged lateral walls with folds compressed like ridges in the angles, are found on the lower surface of the leaf in *Lithospermum purpureo-coeruleum* and *Pulmonaria* (Jodin).

For the **hairy covering** see also Revedin's detailed statements (loc. cit.), which refer to species of *Alkanna, Amsinckia, Anchusa, Asperugo, Caccinia, Echinospermum, Echium, Heliotropium, Lithospermum, Lycopsis, Myosotis, Nonnea, Omphalodes, Onosma, Onosmodium, Pulmonaria, Solenanthus, Symphytum, Tournefortia, Trachystemon* and *Trichodesma*.

To the special description of the trichomes we may add that bracket-hairs occur side by side with other forms of trichomes also in *Anchusa officinalis*, L., and that almost spherical cystolith-hairs, provided with a short pointed filiform process, accompany other types in *Symphytum officinale*, L. In the glandular hairs of *Nonnea pulla*, DC. which have uniseriate stalks and unicellular heads, the lowest of the four or five cells composing the stalk is very strongly developed and forms a kind of pedestal. The stalk of the glandular hairs, found on the calyx in *Tourne-*

fortia fruticosa, R. Br., likewise shows a special type of differentiation, two of the four component cells (viz. the lowest and the next but one above it) being distended in a barrel-shaped manner near their upper end, while the other two are developed as short neck-cells.

In the species investigated by Jodin the **petiole** may contain as many as twelve isolated vascular bundles (generally 5–6 or only 3), the number being connected with the differentiation of a furrow of varying breadth; the median vascular bundle alone is strongly developed as an arc of wood and bast.

3. Structure of the axis. For the detailed structure of the stem in the herbaceous members of the Order, see Jodin. The primary cortex in these forms is loose and occasionally contains palisade tissue; in *Echium vulgare* it includes strongly sclerosed cells. The pericycle is generally parenchymatous, and rarely (*Heliotropium curassavicum*) contains groups of fibres. The vascular bundles are either isolated or fused to form a ring of wood and bast. A composite and continuous ring of sclerenchyma has recently been observed by Pitard in the pericycle of *Tournefortia hirsutissima*.

Note. According to Jodin the **root** of the herbaceous Boragineae generally contains a diarch vascular system, although this does not apply to the adventitious roots of the rhizome, which show 5–6, sometimes even as many as twelve, radial vascular bundles, two bundles only being found as an exception (*Symphytum tuberosum*). The development of the cork in the root takes place in the pericycle (*Alkanna, Borago, Echium, Pulmonaria*). Regarding the red coloration shown by the roots of many Boragineae, see Norton (in Missouri Bot. Garden Report, 1898, pp. 149–51) and other authorities.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 134 et seq.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 20.—Minden, Wassersez. Org., Bibl. bot., Heft 46, 1899, p. 23.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 39, 65 and 104.—[Baldacci, *Symphytum orientale*, Rendiconti Accad. Bologna, iv, pp. 74–8; abstr. in Just, 1902, ii, p. 280.]—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 49, 50 (*Echium*).—Preston, in Bot. Gazette, 1902, pp. 150–4 (*Amsinckia*).—Revedin, Peli delle Boragin., Nuovo Giorn. bot. Ital., N. S., ix, 1902, pp. 301–18.—Jodin, Rech. anat. sur les Boragin., Ann. sc. nat., sér. 8, t. xvii, 1903, pp. 263–346, pl. 5–9 (deals only with the European genera, and with *Amsinckia*).—Theorin, Vaxttrichom., Arkiv för Bot., 1, 1903, p. 158; iii, n. 5, 1904, pp. 26, 27; and iv, n. 18, 1905, p. 22.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 68, 69.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 45.—[Vidal, *Eritrichium nanum*, Assoc. franç. Cherbourg, 1905, pp. 472–5.]—[Kimpflin, Affinités des Boragin. et des Lamiacées, Assoc. Avanc., 35 Sess., Lyon, 1906, pp. 428–31.]—[Kramer, Mikr.-pharm. Beitr., Diss., Würzburg, 1907, p. 29 (*Pulmonaria*).]

CONVOLVULACEAE (pp. 562–573).

To the discussion of the internal **secretory system** (see pp. 565, 566) we may in the first place add that according to a written communication from Hallier the axes in all the higher Convolvulaceae (Ipomoeeae, Argyreieae, and *Merremia*) contain a white or whitish sap. The secretory organs found in the flower have been examined in detail by Grélot. According to him the floral organs likewise contain secretory cells (isolated and in rows), as well as cell-fusions, the latter occurring in *Falkia* and *Dichondra*. Grélot, like the earlier observers (cf. footnote 3 on p. 565), maintains that he has encountered resorption of the transverse walls in the rows of laticiferous sacs.

As regards the **glandular hairs** (see pp. 568, 569) reference may be made to the large external glands, which are situated on the lower side of the leaf in *Stictocardia tiliaefolia*, Hallier, and are provided with a head showing vertical division, and to the pore-like perforation of the cuticle observed in the ordinary peltate glands of *Operculina Turpethum*, Peter (Svedelius).

APPENDIX: I. CUSCUTEAE (p. 573).

Our knowledge of the anatomy of the Cuscuteae has been quite materially improved by recent investigations undertaken by Cornu and especially by Mirande[1].

The **secretory organs** of the Cuscuteae consist of secretory cells, which may be distinguished as cortical (situated in the primary cortex), pericyclic and medullary according to their point of occurrence in the stem. Cortical and pericyclic secretory cells are found in all the species of *Cuscuta*, and constitute two characteristic zones in the thin stems of these forms, while medullary secretory cells have been observed only in *Cuscuta americana*; the latter show the same structure as the elements situated in the cortex. In the young parts of the axis the zone of cortical secretory cells lies in the peripheral portion of the primary cortex. In the older parts of the axis these elements are more or less separated both from one another and from the epidermis as a result of the cell-divisions which have taken place in the primary cortex. In the young parts of the axis the cortical secretory cells are moderately elongated, and form vertical rows of cells, which can be distinguished from the neighbouring cells even by their size; in the Monostyleae (Subgenus *Monogynella*, Engelm.) their nucleus occupies a peripheral position, while in the Distyleae (Subgenus *Grammica* and *Cuscuta*) it lies in the centre of the cell. In later stages the cells often elongate very considerably. The neighbouring short cells of the cortex then frequently exert a pressure on the longitudinal walls of the secretory sacs, so that dents are produced, which in the case of secretory sacs isolated by maceration appear as a system of facets, corresponding to the cellular network of the adjoining cortical cells. Except for this the wall of the secretory sacs is either smooth or finely punctate. The pressure exerted by the turgescent cortical cells also commonly leads to the almost complete compression of the cortical secretory cells in the older parts of the axis, so that they easily escape observation. The zone of pericyclic secretory cells is likewise typically developed only in the young stems, but for them it is highly characteristic, the cells being readily recognized owing to their wide lumina. The pericyclic secretory cells also become separated from one another in later stages; their lumina then occasionally become narrowed as a result of intercalary growth, or the cells may acquire very thick walls and come to resemble fibres; in other cases they retain their thin walls, but lose their rounded outline in transverse section and look like star-shaped intercellular spaces. This accounts for the fact that the earlier observers failed to place a correct interpretation on the pericyclic secretory cells. In the Monostyleae the membranes of the pericyclic secretory cells become more or less lignified, while in the Homostyleae (Subgenus *Cuscuta*) they generally continue to consist of cellulose; in the Heterostyleae (Subgenus *Grammica*) the membranes ultimately become thick, cartilaginous and refractive, and acquire the property of swelling up in the presence of water, the cells at the same time assuming a fibre-like appearance. In the last stage the pericyclic secretory cells constitute long tubes, the length of which in the Monostyleae and Homostyleae occasionally equals that of five internodes, although shorter in the Heterostyleae. Neither

[1] Mirande's investigations deal with the following species: I. Monostyleae: *Cuscuta cassythoides*, *C. exaltata*, *C. japonica*, *C. Lehmanniana*, *C. lupuliformis*, *C. monogyna*, *C. reflexa*, *C. timorensis*. II. Distyleae: a. Homostyleae: *C. abyssinica*, *C. africana*, *C. arabica*, *C. babylonica*, *C. brevistyla*, *C. capitata*, *C. Epilinum*, *C. Epithymum*, *C. europaea*, *C. nitida*, *C. palaestina*, *C. parviflora*, belonging to the type of *C. europaea*; b. Heterostyleae: *C. decora*, *C. Gronovii*, *C. inflexa*, belonging to the type of *C. Gronovii*; *C. californica*, *C. chilensis*, *C. chinensis*, *C. corymbosa*, *C. cuspidata*, *C. floribunda*, *C. glomerata*, *C. hyalina*, *C. jalapensis*, *C. odorata*, *C. rostrata*, *C. sandwichiana*, *C. tenuiflora*, *C. umbellata*, belonging to the type of *C. chinensis*; *C. americana*, forming a special type of its own.

branching nor anastomosis has been observed in the secretory cells. A very noteworthy feature lies in the fact that the pericyclic secretory cells contain several ellipsoidal or fusiform nuclei in place of a single one. The chemical nature and surface-markings (punctation or striation) of the wall are subject to variation, occasionally even in one and the same cell. Of the secretory cells occurring in the stem as a rule only the cortical elements can be traced into the scaly leaves. In the latter, and especially in the lower part of the scale-leaf, they frequently form a complete hypodermal layer of rather short cells with wide lumina above the lower epidermis; in the upper part of the leaf the secretory cells decrease in number and ultimately occur only as isolated elements. The protoplasmic contents of the secretory cells soon disappear, the mature elements chiefly containing oily substances, tannins and resins.

An important systematic feature concerning the differentiation of the **fibrovascular system** of the stem is that in the Monostyleae (the stem being in that stage of development in which the vascular bundles are fully differentiated, but have not yet begun to grow in thickness) the xylem-groups of the vascular bundles, which show an annular arrangement, are united to form a strengthening ring by means of groups of elongated sclerenchymatous cells resembling fibres, while in the Distyleae this is not the case. In the Distyleae, moreover, the entire fibrovascular system, and especially the xylem-groups of the bundles, show a greater degree of reduction than in the Monostyleae.

Among the Monostyleae the vascular bundles are most strongly developed in *Cuscuta japonica*, in which they also show growth in thickness in later stages. Even in this species, however, strands of mestome, which are essentially of the nature of phloem-bundles, occur side by side with the fully differentiated bundles (i. e. those containing both wood and bast) of the vascular ring; these phloem-bundles are either apposed to the outer side of the sclerenchymatous strengthening ring or are embedded in it. The xylem-groups of some of the vascular bundles, moreover, do not extend through the entire thickness of the strengthening ring, being separated by a bridge of sclerenchyma from the corresponding bast-group. The process of secondary growth does not take place uniformly in the vascular bundles of *C. japonica*. This results in the bursting of the strengthening ring, while the vascular bundles themselves present a varied appearance in transverse section. Side by side with the normal bundles of wood and bast, in which the secondary wood adjoins the primary wood in the ordinary way, one meets with the following types: (*a*) bundles in which groups of sclerenchyma belonging to the original strengthening ring are inserted between the primary and secondary wood (these being the bundles, in which the xylem-groups did not extend through the entire strengthening ring prior to the commencement of secondary growth); (*b*) bundles of wood and bast, which contain no primary wood and are derived from the original phloem-bundles; and lastly, (*c*) groups of interxylary phloem, which owe their development to the cessation of cambial activity in the median of three vascular bundles, lying next to one another, while the two lateral bundles undergo considerable growth in thickness, the new wood thus formed covering in the phloem-group belonging to the median bundle.

In the remaining Monostyleae the vascular system is more or less reduced, as evidenced not only in the absence of growth in thickness, but also in the smaller number of bundles of wood and bast or of phloem and the smaller number of tracheae in the xylem-groups. In the Distyleae reduction has gone even further than in the Monostyleae.

The pericycle in the Monostyleae besides containing secretory sacs also includes groups of bast-fibres. The sieve-tubes, which are often developed in large numbers and frequently have wide lumina, have horizontal or oblique sieve-plates with one or more sieve-areas; their longitudinal walls show manifold types of structure, but bear sieve-areas only in the Monostyleae.

The structure of the pith varies in the monostylic species. In *Cuscuta cassythoides*, *C. Lehmanniana*, *C. monogyna* and *C. timorensis* it is sclerosed

except for small islands of thin-walled tissue in the neighbourhood of the primary xylem-groups, while in the remaining species the walls of the medullary cells consist of cellulose.

According to Mirande the nature of the **intercellular system of the stem** is likewise a feature of systematic importance. The Monostyleae and Homostyleae have small lacunae, occurring especially in the primary cortex; in both cases these lacunae are enveloped by parts of the walls of the adjoining cells, these portions of the wall being suberized in the Monostyleae and cutinized in the Homostyleae. In the Heterostyleae of the type of *C. chinensis* and *C. americana* the primary cortex and bast contain canals and cavities, having cutinized walls. Very commonly, moreover, lacunae may also be observed on the inner side of the vascular bundles, these cavities arising by abortion of the primary vessels, in the same way as in many Monocotyledons and Dicotyledonous aquatics.

Finally, according to Mirande, the axes of the Cuscuteae are characterized also by the presence of a peculiar **sheath of cells** ('gaîne nourricière') having abundant protoplasmic contents and developed as a complete envelope to the individual vascular bundles; this sheath is most typically differentiated in the Monostyleae.

The structure of the **scale-leaves**, which are devoid of chlorophyll, may first be described in *Cuscuta japonica*, where they are most strongly developed. A transverse section through the base of the leaf in this species as a rule shows a lower epidermis composed of large cells and an upper epidermis in which the cells are smaller; above the lower epidermis an almost continuous layer of secretory cells is situated, while the vascular bundles are embedded in a homogeneous mesophyll consisting of rounded cells. The cells of the lower epidermis are divided by numerous vertical walls, only a small number of which occur in the upper epidermis. Only the lower epidermis contains stomata, which are rather numerous; stomata are altogether not as rare in the Cuscuteae—even on the different parts of the stem—as has hitherto been supposed. As we approach the cucullate apex of the scale-leaf the subepidermal secretory sacs show a considerable decrease in number; the main mass of the apex is constituted by a group of small-celled tissue, which occupies a central position and is formed by the division of the tissue accompanying the fibrovascular system. Occasional leaves, which are particularly strongly developed, even have typical palisade tissue containing sclereids on their upper side. Of the vascular bundles entering the leaf, the median one at first retains its complete structure; in its further course, however, its xylem soon disappears, and a phloem-bundle remains, from which branches are given off to the group of tissue situated in the centre of the cucullate apex of the leaf. The two lateral vascular bundles lose their xylem-groups on entering the leaf, while the remaining lateral bundles passing into the leaf already leave the axis in the form of phloem-bundles. In *C. exaltata* the structure of the leaf is similar to that of *C. japonica*. In the remaining Monostyleae and in the Distyleae the structure of the leaf is reduced to a varying extent.

2. Nolaneae (p. 573).

According to Mirande alcohol-material of *Nolana paradoxa* contains sphaerocrystalline masses, consisting of calcium malophosphate and neutral calcium malate, of which the former is more abundant.

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SOLANACEAE (pp. 575–583).

1. Review of the Anatomical Features. To the list of special features found in certain members of the Order we may add the occurrence of: arm-palisade parenchyma (*Protoschwenkia* and species of *Schwenkia*); peculiar thickened palisade-cells (species of *Dyssochroma, Juanulloa* and *Markea*); cells of the spongy tissue with swollen areas on the walls (*Melananthus guatemalensis*, Solered.); and tannin-sacs (*Solandra grandiflora*, Sw.).

2. Structure of the Leaf. Arm-palisade tissue is developed in *Protoschwenkia Mandoni*, Solered., as well as in *Schwenkia brasiliensis*, Poir., *S. divaricata*, Benth., *S. grandiflora*, Benth., *S. Karstenii*, Vatke, *S. mollissima*, Nees et Mart. and *S. patens*, H. B. K. With reference to its differentiation we may note that the folds, which are united to form lamellae, as a rule project singly from above and below into the lumen of the cell, and that the two compartments thus formed in the palisade-cell communicate with one another by means of an approximately circular aperture. In *Dyssochroma viridiflora*, Miers, *Juannulloa aurantiaca*, Otto et Dietr., *J. membranacea*, Rusby and *Markea coccinea*, Rich. the cells of the palisade tissue are distinguished by the fact that their walls, and especially the longitudinal ones, are strengthened by means of thickening ridges, which run in a direction parallel to the length of the cell and are occasionally connected by means of transverse ridges. In *Trianaea nobilis*, Pl. et Lind. and *T. speciosa*, Solered. the mesophyll, and especially the spongy tissue, includes sclerosed cells. In *Melananthus guatemalensis*, Solered. the spongy tissue likewise exhibits a peculiar type of structure; at certain points the walls of the cells show swellings, recalling the thickened parts of the wall in collenchymatous tissue (Solereder).

In the species of *Datura* (sect. *Brugmansia*) examined by Lagerheim the lower **epidermis** of the leaf contains chlorophyll. The stomata in the species of *Trianaea* are distinguished by having peculiar coma-shaped depressions, which are situated at both ends of the two guard-cells and run obliquely to the direction of the pore, the thickened part of the coma being directed outwards (Solereder).

No new types of **hairs** (see p. 576) have been recorded. I have observed branched multicellular hairs also in *Anthocercis albicans*, A. Cunn., *A. littorea*, Labill., *A. tasmannica*, Hook. fil., *Anthotroche pannosa*, Endl., *Juanulloa membranacea*, Rusby, *J. Sargii*, J. D. Smith, *Solandra grandiflora*, Sw. (here side by side with unbranched hairs); according to Kearny they occur also in *Physalis viscosa*, L. (here showing dichotomous branching). Combined clothing

and glandular hairs occur in *Solandra grandiflora*, the branched trichomes of this species commonly bearing spherical glandular cells at the ends of their branches. Hairs of this type are found also in *Nicotiana Tabacum*, but in this species the glands, borne on the branched trichomes, are both unicellular and multicellular. External glands having a unicellular head have recently been observed also in species of *Datura* belonging to the section *Brugmansia* (here side by side with glands having multicellular heads), in *Isandra Bankroftii*, F. v. M. and *Protoschwenkia Mandoni* (here together with glands having multicellular heads); glands having a multicellular ellipsoidal head, divided by horizontal walls only or both by horizontal and vertical walls, have been found also in species of *Anthotroche* (with rather long stalks), *Protoschwenkia* (with stalks of varying length), and *Dyssochroma*, *Juanulloa*, *Markea*, *Solandra*, *Trianaea* (stalks in these cases short). The cells of the external glands occasionally (*Nicotiana Tabacum*) contain oxalate of lime in the form of small clustered crystals.

For the **spines** of *Datura* and *Solanum*, in the formation of which ground tissue participates, see also Lothelier and Mittmann.

The **tannin-sacs** above mentioned are stated to resemble those of the Leguminosae and have been recorded by Pistone in the stem and root of *Solandra grandiflora*.

To the earlier statements regarding the occurrence of **oxalate of lime** in this Order we may add that typical crystal-sand has now been demonstrated also in *Dyssochroma*, *Juanulloa*, *Markea* and *Trianaea*, and that in *Protoschwenkia* oxalate of lime occurs only in the axis, being present in the form of a crystal-sand composed of fusiform, prismatic or acicular crystals of varying size. In *Anthotroche pannosa*, as well as in other members of the Order, the typical crystal-sand includes relatively large tetrahedral crystals (Solereder).

3. Structure of the Axis. Recent observations have shown that the vascular system exhibits bicollateral differentiation also in *Protoschwenkia* and *Trianaea* (cf. footnote 3 on p. 579).

Leisering's recent investigations have likewise failed to completely elucidate the mode of development of the **interxylary phloem** (see p. 580). The latter occurs also in the wood of the root of *Browallia viscosa*, H. B. K. (Scott and Brebner), and in the rhizome of *Atropa Belladonna* (Beauvisage).

The wood-prosenchyma bears bordered pits in *Protoschwenkia*, and simple pits in *Trianaea*. In both genera the perforations of the vessels are simple, and the medullary rays of the wood narrow.

To the section dealing with the structure of the **cortex** (p. 581) we may add that the development of the cork commences in the epidermis also in *Protoschwenkia*.

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SCROPHULARINEAE (pp. 583-589).

2. Structure of the Leaf. The peculiar hydathodes of *Herpestis Monnieria*, H. B. K., which are described by Boergesen and Areschoug and consist of a small conical cell situated above an ordinary epidermal cell, require further investigation. The same applies to the stalked club-shaped bodies resembling cystoliths, observed by Ward and Dale in *Craterostigma pumilum*, Hochst., where they are found attached to the outer wall of the epidermal cells. Isolated stomata are found on the scale-leaves in the parasitic form, *Hyobanche sanguinea* (Chatin).

According to Heinricher protein-**crystals** are found embedded in the nuclei in all the organs of *Lathraea* and *Tozzia*; in *Lathraea* they occur also in the protoplasm and in the leucoplasts. Red granules of a substance not quite identical with carotin have been demonstrated in *Craterostigma pumilum*; they are chiefly found as a lining to the intercellular spaces in the cortex of the root, being the cause of the coral-red coloration of the latter, but they also occur in the axis in the same position as in the root and in the lower half of the mesophyll of the leaf. Rothert's and Zalenski's (Bot. Centralbl., 1899, iv, p. 246) statement as to the presence of styloids in the pith and cortex of *Phyllopodium* ('*P. rigidum*') still awaits confirmation.

Glandular **hairs** of the ordinary type are present also in *Peliostomum* (Weber).

3. Structure of the Axis. In *Capraria biflora*, L. Ph. Wagner records subepidermal development of the cork, isolated groups of bast-fibres in the pericycle, and groups of stone-cells in the pith. In *Herpestis Monnieria* Duval mentions the occurrence of peculiar mechanical cells situated in the lacunar tissue of the primary cortex; these elements are parenchymatous in shape and are provided with ridge-like thickenings. According to Weber the pericycle contains isolated bundles of fibres or a more or less interrupted ring of fibres in *Aptosimum* and *Peliostomum*, while in some of the species of *Peliostomum* (*P. origanoides*, E. Mey., *P. virgatum*, E. Mey., *P. viscosum*, E. Mey.) subepidermal groups of fibres are found in the tips of the branches, although not of constant occurrence even in one and the same species.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 125 et seq.—Costantin, Tiges d. pl. aquat., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 et seq. and pl. xvi, xvii.—Scherffel, in Bot. Zeit., 1890, p. 417 et seq.—Stock, Proteinkrystalle, in Cohn, Beitr., vi, 1893, p. 213 et seq.—[Breithaupt, Struct. of *Leptandra*, Pharm. Journ., lxix, 1897, n. 5 (*Veronica virginica*, L.); abstr. in Just, 1897, ii, p. 54.]—Schubert, Parenchymscheiden, Bot. Centralbl., 1897,

iv, p. 62.—Ph. Wagner, Neuere Drogen, Diss., Erlangen, 1897, pp. 35-47 (*Capraria biflora*).—Weinrowsky, Scheiteloffn. bei Wasserpfl., Diss., Berlin, 1898, p. 33 (*Veronica Anagallis*).—Hirsch, Entwickl. d. Haare, Diss., Berlin, 1899, p. 28.—Lavadoux, Appareil pilifère des Verbascées, Journ. de Bot. 1899, pp. 216-18.—Minden, Wasserausz. Org., Bibl. bot., Heft 46, 1899, p. 36.—Ward and Dale, *Craterostigma pumilum*, Transact. Linn. Soc., v, 1899, pp. 343-55 and pl. xxxiv, xxxv.—Heinricher, Eiweisskrystalle bei *Lathraea*, in Pringsheim Jahrb., xxxv, 1900, pp. 28-46.—Kearny, in Contribut. U. S. Nat. Herb., v, n. 5, 1900, p. 305 (*Herpestis Monnieria*).—Thomas, Feuilles sout., Thèse, Paris, 1900.—Heinricher, Anat. d. *Tozzia*, in Pringsheim Jahrb., xxxvi, 1901, pp. 713-27.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 89.—Areschoug, Mangrovepfl., Bibl. bot., Heft 56, 1902, pp. 78, 79, Tab. viii.—Sperlich, Inhaltsst. in den Saugorg. d. gr. Rhinanthac., Beih. z. bot. Centralbl., xi, 1902, p. 437 et seq.—[Armari, Piante della reg. medit., Ann. di Bot., i, 1903, p. 17 et seq. (*Linaria*).]—Theorin, Vaxttrichom., Arkiv for Bot., i, 1903, p. 155.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 111.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 71-3.—Sussenguth, Behaarungsverh. d. Wurzb. Muschelkalkpfl., Diss., Würzburg, 1904, pp. 45, 46.—Theorin, Vaxttrichom., Arkiv for Bot., iii, n. 5, 1904, pp. 16 and 28.—Daguillon, *Linaria striato-vulgaris*, Revue gén. de bot., 1905, pp. 508-18.—Porsch, Spaltoffnungsapparat, Jena, 1905, pp. 65-8.—Weberbauer, Veget. d. Hochanden Perus, in Engler, Bot. Jahrb., xxxvii, 1905, p. 60 et seq.—Duval, Jaborandis, in Perrot, Travaux, iii, 1906, pp. 90 4 (*Herpestis*).—[Bohny, *Digitalis*-Blatt, Diss., Zürich, 1906.]—Piccioli, Legnami, Bull. Siena, 1906, p. 176.—E. Weber, *Aptosimum* und *Peliostomum*, Beih. z. bot. Centralbl., xxi, Abt. 2; also Diss., Zürich, 1906, 101 pp., 3 Tab.—Sperlich, Zellkernkrystalloide von *Alectorolophus*, Beih. z bot. Centralbl., xxi, Abt. 1, 1907, p. 1 et seq.—Kranzlin, in Pflanzenreich, Heft 28, 1907, p. 2.—[Huchedé, Véroniques et Gratiole, These, Paris, 1907, 137 pp.; also in Perrot, Travaux, v.]

OROBANCHACEAE (pp. 589-591).

Among the Orobanchaceae, which have a single ring of **vascular bundles** in their axis (cf. p. 590), we may include *Aphyllon uniflorum*, Gray, in which the bundles form a more or less continuous ring (A. C. Smith). Cooke and Schiveley's statement as to the occurrence of bicollateral vascular bundles in the stem of *Epiphegus virginianus* requires confirmation, the more as the authors named did not observe distinct sieve-plates even in the outer phloem.

Contrary to the earlier statement, **stomata** are found on the floriferous axis (although not on the leaves) in *Conopholis americana*; they are also present in *Aphyllon uniflorum*, where they occur on the axes, bracts and floral organs.

Literature: Duchartre, Anat. de l'*Orobanche Eryngii*, Ann. sc. nat., sér. 3, t. iv, 1845, pp. 74-9.—Lory, Resp. et struct. d. Orobanch., Ann. sc. nat., sér. 3, t. viii, 1847, pp. 158-72.—Wilson, *Conopholis americana*, Contribut. Bot. Laborat. Pennsylvania, ii, n. 1, 1898, pp. 3-19, pl. i-vi.—A. C. Smith, *Aphyllon uniflorum*, Contribut. Bot. Laborat. Pennsylvania, ii, n. 2, 1901, pp. 111-21, pl. xiii-xv.—Cooke and Schiveley, *Epiphegus virginiana*, Contribut. Bot. Laborat. Pennsylvania, ii, n. 3, 1904, pp. 352-98, pl. xxix-xxxii.—Porsch, Spaltöffnungsapparat, Jena, 1905, pp. 60-5.

LENTIBULARIEAE (pp. 591-598).

To the **review of the anatomical features** we may make the following additions. In connexion with the remarks on the uniform type of structure shown by the glandular hairs, we may note that in place of a single stalk-cell there may be several. Dissociation of the vascular bundles of the stem into xylem- and phloem-groups, which are independent of one another, occurs also in *Polypompholyx*[1].

1. PINGUICULA (pp. 591, 592)

The structure of the leaf in *P. vulgaris* has recently been examined by Fenner. In rectification of the earlier statements we may first mention that chlorophyll is found in the epidermis of the leaf in the neighbourhood of the midrib, and that stomata are present on both sides and are even more abundant on the upper side;

[1] **For *Byblis*, which has been transferred to the Lentibularieae by Lang, see under Droseraceae, p. 912.**

they are absent only from the marginal zones on both surfaces of the leaf. The **glandular hairs** occurring on the upper side of the leaf are either stalked or sessile. The stalked glands, which function as organs for the capture of the insects, consist of (1) a basal cell, (2) a stalk composed of one to three cells, (3) a columella-cell, and (4) a head comprising 16 radially arranged cells. The shortly stalked glands have a basal cell, a stalk-cell, and a glandular disc of 4 or 8 cells; these are the glands which perform the actual process of absorption. The same function is carried on also by one to four rows of upper epidermal cells lying next to the margin of the leaf and styled glandular cells by Fenner. The lower side of the leaf only bears small external glands, which are provided with a head composed of four cells and function as hydathodes. Features deserving special mention are the sieve-like perforation of the cuticle of the glandular head, and the fact that tracheae of the vascular system extend up to all the glands (both sessile and stalked) on the upper side of the leaf. Multicellular trichomes, which do not have a secretory function, occur on the petiole and on the base of the lamina; these hairs either consist of a row of 3–6 cells or bear a rudimentary head, which is unicellular or composed of a small number of cells; the nuclei in these hairs contain crystalloids. According to Russow and Klein, moreover, nuclear crystalloids are found also in the epidermis of the leaf, &c.

2. GENLISEA (pp. 592–594).

For the structure of the ascidiform leaves of *G. violacea*, St. Hil., which is essentially the same as in *G. ornata*, see Goebel, loc. cit.

3. UTRICULARIA (pp. 594–597).

The most important point in Meierhofer's recent investigations on the anatomy of the **bladders** is the statement that there is no stalk-cell in the two-armed glandular hairs (with upwardly directed arms) occurring on the inner wall of the lower lip (which faces the interior of the bladder) and in the four-rayed absorptive glands on the 'inner wall of the bladder.' According to Meierhofer the apparent stalk in the two types of hairs is—in *Utricularia vulgaris* at least—formed by the lower portions of the 2 or 4 ray-cells, which are narrowed so as to resemble a stalk. According to the same authority, moreover, the lid in *U. vulgaris*, which, like that of *U. flexuosa*, is composed of two layers of cells provided with peculiar stiffening-mechanisms, bears glands which for the most part consist of three cells, the head being unicellular and of varied shape, viz. spherical, ellipsoidal or like the terminal portion of a two-armed hair. In some cases the head of these glands is bicellular owing to the presence of a vertical wall, or the stalk-cell (joint-cell) undergoes secondary division into four cells by means of vertical walls. The four-armed absorptive glands, which occur on the inner wall of the bladder, may be used as a means of distinguishing the species; in *Utricularia Bremii*, Heer they show the same arrangement of the ray-cells as in *U. minor* (see Fig. 139, *D*, on p. 596), while in *U. intermedia*, Hayne the ray-cells are arranged in pairs in two parallel rows in the same way as in *U. montana* (Fig. 139, *E*). On the surface of the bladder of *U. intermedia* Meierhofer observed glandular hairs with 4-celled heads in addition to those having 2-celled heads.

4. POLYPOMPHOLYX (p. 597)

The anatomy of this genus of the Lentibularieae was hitherto little known; two Western Australian species, *P. multifida*, F. v. Müll. and *P. tenella*, Lehm., have, however, recently been examined by Lang. The two species agree with one another as regards their anatomy.

In the structure of the **axis** the vascular system is specially distinguished by the absence of proper vascular bundles, the xylem- and phloem-groups running independently of one another as separate strands. The xylem- and phloem-bundles are present in equal numbers, the former consisting only of one vessel apiece, while the phloem-bundles comprise a group of small cells including sieve-tubes. Both kinds of bundles are inserted in a ring of sclerenchyma composed of cells resembling fibres; on their inner side these cells merge into a pith made up of large cells. The bundles alternate with one another like the wood- and bast-groups

in the radial vascular system of a root, the phloem-bundles lying at the periphery of the sclerenchymatous ring and bordering on the sheath of large parenchymatous cells which adjoins the ring of sclerenchyma on its outer side. The primary cortex contains intercellular spaces which, near the points of insertion of the leaves and stolons, are of large size and are arranged in a ring; they are separated from one another by lamellae composed of a single layer of cells, and border on the sub-epidermal layer externally and on the sheath of large parenchymatous cells internally. The vascular system of the stolons consists of a single bundle showing concentric structure, the middle being occupied by a solitary vessel, the place of which is subsequently taken by an intercellular space.

The **foliage-leaves** have epidermal cells (occasionally containing chlorophyll) with more or less undulated lateral walls and bear stomata on both sides. The mesophyll is homogeneous and is provided with cavities which are particularly prominent on the lower side and attain considerable width in the neighbourhood of the petiole. The solitary median vascular bundle of the leaf contains only one vessel and is—at least at certain points of its course—collateral. The hairy covering of the leaf is constituted by external glands consisting of three cells, viz. a sunken basal cell, a stalk-cell, and a capitate cell secreting mucilage.

For the shape of the ascidiform leaves or **bladders**, see p. 597. The wall of the bladder consists of four layers of cells and is traversed both on the dorsal and ventral side by a well-differentiated vascular bundle, running in the median plane. The outer wall of the bladder bears the ordinary 3-celled glands, while at points situated opposite the ciliate margin of the cap one finds bristle-hairs like those occurring on the latter and consisting of a basal cell, a short stalk-cell and a long terminal cell. The inner wall of the bladder is occupied by the same characteristic four-armed absorptive hairs, as are found in *Utricularia*; in the species examined by Lang the arms of these hairs are arranged in the form of an ×. The wing-like extensions of the cap have the ordinary external glands on their outer surface, while the inner surface bears numerous glands secreting mucilage and exhibiting all transitions between the ordinary capitate glands and glandular hairs with flagelliform terminal cells; the terminal cell may be spherical, ellipsoidal or clavate or in extreme cases flagelliform. The inner wall of the stalk, which here likewise participates in the formation of the wall at the entrance to the bladder, also bears glands with terminal cells, which are flagelliform and are often bent in the form of a crook; in addition to these one finds glands with two-armed terminal cells, the arms being placed parallel to the surface. The inner wall of the 'lid,' which is composed of two layers of cells, strengthened by means of annular or spiral thickening bands, and the inner wall of the 'lower lip' ('Widerlager') are likewise occupied by numerous flagelliform mucilage-hairs. On those parts of the lip, which are situated nearer the interior of the bladder, the mucilage-hairs are replaced by glands with two-armed panduriform heads divided by a transverse wall into two cells, while the place of the mucilage-hairs on the lower lip is taken by a tessellated epithelium composed of closely crowded capitate glands of the ordinary type. Finally, on that part of the lower lip, which faces the interior of the bladder, we find the same two-armed glands provided with upwardly directed arms, as occur in *Utricularia flexuosa*, &c.

Literature: J. Klein, Zellkerne von *Pinguicula* u. *Utricularia*, Bot. Centralbl., 1880, iii, pp. 1401–4.—Russow, Krystalloide bei *Pinguicula*, Sitz.-Ber. Dorpat. naturf. Gesellsch., 1880, pp. 417, 418.—Goebel, *Genlisea*, Flora, 1893, pp. 208–12.—[Endo, *Utricularia bifida*, Bot. Magaz. Tokyo, xii, 1898, pp. 1–4, 1 pl.]—Weinrowsky, Scheitelöffn. bei Wasserpfl., Diss., Berlin, 1898, p. 36.—Meister, *Utricularia*, Bull. Herbier Boissier, 1900, n. 12, 40 pp., Tab. i–iv.—Lang, *Polypompholyx* u. *Byblis*, Flora, 1901, pp. 152–66, Tab. xii.—Meierhofer, *Utricularia*-Blasen, Flora, 1902, pp. 84–113, Tab. ii–v.—Dutailly, in Assoc. franç. Ajaccio, 1902, p. 457.—Fenner, Laubbl. u. Drüsen einiger Insektivoren, Flora, 1904, p. 335 et seq.; also as Diss., Zürich, especially pp. 6–20, Tab. vi–viii.

COLUMELLIACEAE (p. 598).

Van Tieghem has recently examined the remaining known species, viz. *Columellia oblonga*, Ruiz et Pav., *C. obovata*, Ruiz et Pav. and *C. sericea*, H. B. K. In these species he records the following features which agree with those observed by me in *C. serrata*, Rusby:—uniseriate medullary rays in the wood; peri-

cyclic development of the cork, which has the same composition as in *C. serrata*; absence of secondary hard bast; clustered crystals of oxalate of lime; bifacial leaf-structure; stomata confined to the lower side of the leaf and without subsidiary cells; simple unicellular clothing hairs adpressed to the surface of the plant; no glandular hairs; and lastly, in all the species, a single layer of hypoderm on the upper side of the leaf.

The following details may still be added. The mode of development of the cork in *Columellia obovata* recalls that in *Dodonaea* (Order: Sapindaceae). The pericycle is parenchymatous. One of the outer layers of pericyclic cells gives rise to the first phellogen and forms a periderm on its outer side in which there is a regular alternation of layers of suberized cells, showing marked radial elongation, and small flat cells with cellulose walls, which subsequently become sclerosed. This is followed by the development of a first continuous ring of fibres from pericyclic tissue adjoining the cork-cambium; the first phellogen then ceases to be functional and a second one arises on the inner side of the ring of fibres from tissue belonging either to the pericycle or to the bast; this second phellogen produces a new periderm, the structure of which is identical with that of the first-formed one. While the second periderm is in course of formation a second ring of sclerenchyma is differentiated on the inner side of the second cork-cambium; internal to this sclerenchymatous ring a third cork-cambium is produced after the activity of the second has been brought to a close, and so on. In the other two species Van Tieghem observed noteworthy modifications; thus in *C. sericea* the (first) ring of pericyclic fibres is present before the development of cork commences, while in *C. oblonga* it continues to thicken for some considerable time before the second phellogen appears. In the three species, which he examined, Van Tieghem also records an endodermis composed of large cells with lignified radial walls and situated on the outer side of the pericycle. The leaf is supplied by a vascular bundle, taking the form of an arc of wood and bast. The vascular bundle found in the median vein of the leaf is provided with an arc of fibres.

Literature: Van Tieghem, Columelliacées, Bull. Mus. d'hist. nat., 1903, pp. 233–9; and Ann. sc. nat., sér. 8, t. xviii, 1903, pp. 155–64.

GESNERACEAE (pp. 599–601).

To the Summary of the Anatomical Features of the Gesneraceae we may add the following details. Typical bundles of raphides occur in *Napeanthus repens*, J. D. Smith (genus novum Gesneracearum); true cystoliths have been observed in the two very closely related genera *Klugia* and *Rhynchoglossum*; secretory canals, developed in relation to the vascular bundles of the leaf and stem, as well as medullary vascular bundles in the stem, are found likewise in *Klugia* and *Rhynchoglossum*, the medullary bundles being present also in *Monophyllaea* and *Coleus*; a single cortical vascular bundle occurs in the stem in *Rhynchoglossum obliquum*, Bl.; stomatal groups are met with on the surface of the leaf in the species of the genus *Napeanthus*; in addition to that certain species have hypoderm in the leaf and spicular fibres in the mesophyll (the latter in *Stauranthera argyrescens*, Hallier f.). As regards the clothing hairs we may note that in the uniseriate trichomes the thick-walled terminal cell, and in some cases also the cell adjoining it, have calcified and silicified walls. Uniseriate trichomes, in which the terminal cell is bent like a hook, occur in *Epithema* and *Loxonia*; simple shaggy hairs are found in certain species of *Klugia* and branched multicellular trichomes in *Klugia zeylanica*, Thw. The heads of the glandular hairs are occasionally unicellular. Special mention may be made of the forked external glands of *Primulina Tabacum*, Hance, and of the 'peltate glands' of *Monophyllaea*, which excrete chalk.

The STRUCTURE OF THE LEAF is again bifacial in the species which I have recently examined. In the species of *Jerdonia* and *Napeanthus* the cells of the spongy tissue are rounded and are peculiar in being connected with one another by means of short peg-shaped processes. According to K. Fritsch (loc. cit.), moreover, similar features are found also in species of *Monophyllaea*, *Streptocarpus* and *Saintpaulia*. There is no sclerenchyma in the **veins** in the species which I have examined; the larger veins commonly (species of *Jerdonia*, *Klugia*, *Loxonia*, *Napeanthus*, *Rhynchoglossum*) include two collateral vascular bundles, which either both show the same orientation (with the xylem on the upper side) or have their xylem-groups directed towards one another. The spicular fibres mentioned above as occurring in the mesophyll in *Stauranthera argyrescens* were observed by Hallier. In *Cyrtandromoea decurrens*, Zoll. the **epidermal cells** on the upper side of the leaf are provided with a small papillose protrusion, arising from the middle of the outer wall. In *Saintpaulia ionantha* the upper epidermis likewise serves for water-storage and consequently consists of large cells (Fritsch); in the species of *Napeanthus* both the upper and lower epidermis show the same feature, the two epidermal layers here occupying the greater part of the transverse section of the leaf. **Hypoderm** is found also in *Codonanthe Devosiana* (according to Schimper), *Aeschynanthus purpurascens*, Hassk. (according to my own observation; here composed of several layers and taking up half the thickness of the leaf), *Monophyllaea Horsfieldii*, R. Br. (according to Fritsch, two-layered), and *Streptocarpus Kirkii*, Hook. f. (according to Fritsch). In *Saintpaulia ionantha* and *Aeschynanthus purpurascens* the spongy tissue likewise stores up water. The **stomata** are often of large size. In *Napeanthus* an excellent generic character is afforded by the stomatal groups, which are often visible even to the naked eye as small spots on the lower side of the leaf and recall the well-known stomatal groups found in certain Begonias. The stomatal groups of *Napeanthus* are constituted mainly by 2–18 pairs of guard-cells together with their subsidiary cells, and are absent only in *N. repens*, J. Donn. Smith, which does not belong to the genus *Napeanthus* (see above).

Regarding the wide distribution of **anthocyanin** in the Gesneraceae, see Hassack and K. Fritsch, ll. cc.

I have observed rather long acicular crystals of **oxalate of lime** also in *Phylloboea amplexicaulis*, Clarke, where they completely fill the cells of the spongy tissue; small but rather distinctly differentiated clustered crystals occur side by side with other small crystals also in the palisade tissue of *Cyrtandromoea decurrens*; relatively large solitary crystals are found in the epidermis of the leaf of *Primulina Tabacum*, and in the palisade tissue of *Acanthonema strigosum*, Hook. f.; large crystalline bodies, which refract the light doubly and give the reactions of oxalate of lime (though still requiring more detailed investigation), are present in the subsidiary cells of the hairs and in enlarged cells of the mesophyll in *Acanthonema strigosum*; lastly, typical bundles of raphides have been observed in spindle-shaped cells in *Napeanthus repens* (genus novum).

Cystoliths have been found among the Gesneraceae in the two genera *Klugia* and *Rhynchoglossum*[1]. The cystoliths vary in shape, being ellipsoidal or more elongated or slightly branched, while in *Klugia ampliata*, Clarke they have a peculiar racemose form; they may or may not be calcified, and are frequently provided with distinct stalks. In *Klugia zeylanica*, Gardn. ('*Klugia Notoniana*,' Hortorum) they are found principally in the palisade tissue, but occur also in the spongy tissue and in the lower epidermis, while

[1] K. Fritsch's paper ('Über das Vorkommen von Cystolithen bei *Klugia zeylanica*' in Wiesner-Festschrift, Vienna, 1908, p. 412) was published while these sheets were in the press.

in *Klugia azurea*, Schlecht., *K. major*, Solered. and *K. Notoniana*, Gardn., as well as in *Rhynchoglossum obliquum*, Bl. (with var. *parviflora*, Clarke) and *R. klugioides*, Clarke they are confined to the lower epidermis, and in *Klugia ampliata*, Clarke to the palisade tissue. I have examined the genera *Napeanthus, Loxonia, Phylloboea, Cyrtandromoea, Jerdonia, Platystemma, Acanthonema*, and *Primulina*, which are placed immediately next to *Klugia* and *Rhynchoglossum* by Bentham and Hooker and other authorities, and find that they do not possess any cystoliths.

Another new anatomical feature, not hitherto recorded in this Order, is constituted by the **resin-canals** found in *Klugia* and *Rhynchoglossum*. I was able to demonstrate their presence in all the species with the exception of *Rhynchoglossum klugioides*, Clarke, of which only a badly preserved fragment of a leaf traversed by Fungi was available. The secretory canals have lumina of varying width and are occasionally surrounded by cells resembling an epithelium; their contents are of a resinous nature. They are found in the first place in the veins of the leaves; in the larger veins they are situated between the two vascular bundles (see above), while in the smaller ones they lie above the xylem of the solitary bundle. In the stem the secretory canals in part accompany the medullary vascular bundles and the bundles of the vascular ring, being placed next to the xylem; but they frequently have an apparently independent course, and run some considerable distance internal to the xylem-groups of the vascular ring.

The **hairy covering** of the Gesneraceae has recently been examined by Rechinger, more especially with reference to the uniseriate clothing hairs, which are provided with strongly thickened terminal cells. According to him the strong thickening of the terminal cell is due to an obliterating membrane ('Ausfüllung'), which is both silicified and calcified. Trichomes of this type, showing obliteration of the lumen in the terminal cell, do not, however, occur in all the members of the Order. In certain species uniseriate hairs are altogether wanting; in other cases one finds uniseriate hairs in which the terminal cell shows no such obliteration of the lumen, while the remaining cells of the hair have walls of varying thickness. Trichomes, in which both the terminal cell and the cell adjoining it, and in rare cases even the third cell from the apex of the hair, show obliteration of the lumen, while the remaining cells have thin walls, were observed by Rechinger in certain species of *Alloplectus, Corytholoma* (= *Gesnera* [1]), *Gesnera, Naegelia, Pearcea* (= *Isoloma*), *Roettlera* (= *Chirita*), *Sciadocalyx* (= *Isoloma*), *Sinningia, Streptocarpus*, and *Tapeinotes* (= *Sinningia*); trichomes, in which the membranes of all the cells are thickened and the lumen of the terminal cell is obliterated, were met with in certain species of *Achimenes, Alloplectus, Centrosolenia* (= *Episcia*), *Drymonia, Jancaea* (= *Ramondia*), *Isoloma, Pentarhaphia, Ramondia, Roettlera* (= *Didymocarpus*), *Streptocarpus* and *Tydaea* (= *Isoloma*). The special structure of the ordinary uniseriate clothing hairs, which has just been discussed, is in general only of value for specific diagnosis. According to Rechinger the same is true also of other structural features shown by these hairs, such as nodular thickenings on the walls (*Achimenes lanata*, Hanst.) or nodose swelling of the basal portions of the individual cells (*Boea hygrometrica*, R. Br., *Jancaea Heldreichii*, Boiss.). Among the members of the Order, which I have recently examined, *Napeanthus repens* alone has long clothing hairs with a terminal cell showing obliteration of the lumen, but in species of *Acanthonema* and *Platystemma* a slight incrustation may be detected at the apex of the terminal cells. Other peculiar types of hairs are: (*a*) the very short pointed hairs of *Napeanthus apodemus*, J. D. Smith, *N. subacaulis*,

[1] According to the Index Kewensis.

Benth. et Hook., &c., which are composed of from one to three cells and are seated on the middle of large epidermal cells; (*b*) the short clothing hairs found in species of *Klugia* and *Rhynchoglossum*, which consist of a small number of cells, the terminal one of which is somewhat bent, and are inserted obliquely on the surface of the leaf; (*c*) the very long uniseriate clothing hairs present on the margin of the leaf in *Jerdonia indica*, Wight, some of the long segments composing these hairs being septate by means of thin transverse walls (to the number of 6 or 7). According to H. Schmidt the uniseriate bracket-hairs already referred to above, in which the terminal cell is bent in the form of a hook, are found in *Epithema Brunonis*, Decne. and *E. carnosum*, Benth.; they constitute a good distinguishing feature between *Epithema* and the genus *Pentaphragma* (Campanuloideae), which is provided with branched clothing hairs, and is often confused with *Epithema* in herbaria. I have observed bracket-hairs also in *Loxonia acuminata*, R. Br. Uniseriate trichomes, in which each of the lower cells is divided longitudinally into two, occur in *Klugia Notoniana*, and constitute a transition to the shaggy hairs, which have been demonstrated in *K. azurea*, Schlecht. and *K. major*, Solered. *Klugia zeylanica*, Gardn. ('*K. Notoniana*' Hortorum, see Rechinger, loc. cit.) is distinguished from the true *K. Notoniana* by the possession of more or less richly branched clothing hairs; the lower part of the stalk in these hairs is frequently biseriate and, like the uniseriate branches, consists of cells with thin walls; I did not see the transparent ('vitreous') unicellular cilia observed and figured by Rechinger, according to whom they are attached to the walls of the hairs with their ends pointing downwards (strange bodies?)[1]. Glandular hairs have recently been demonstrated also in species of *Acanthonema*, *Achimenes*, *Boea*, *Coleus*, *Collandra* (= *Columnea*), *Cyrtandromoea*, *Epithema*, *Gloxinia*, *Jerdonia*, *Klugia*, *Loxonia*, *Monophyllaea*, *Napeanthus*, *Phylloboea*, *Platystemma*, *Primulina*, *Rhynchoglossum*, *Roettlera* (= *Chirita*), *Saintpaulia* and *Tydaea* (= *Isoloma*) (Rechinger, H. Schmidt, Chevalier et Perrot, Solereder). We may add the following details regarding the differentiation of the head. Unicellular spherical glandular heads are found in species of *Coleus*, where they are borne on very short stalks, and in *Napeanthus repens*, where they are placed on very long stalks; long glandular hairs having cylindrical terminal cells, the apex of which is swollen or lageniform, occur in *Primulina Tabacum*, Hance. This species also possesses the forked glands mentioned above; they are long trichomes with a uni-, or rarely bicellular, stalk and two cylindrical terminal cells, which show a pistillate swelling at their apex, are fused for about half their length and diverge beyond that point in a dichotomous manner. In the members of the Order which I have examined the heads of the shortly stalked glands consist of from two to four cells. In the simplest case the bicellular head, as seen from above, has an elliptical outline, while the four-celled head has a rounded or rosette-like outline; as a result of elongation of the glandular cells we obtain glandular heads, which are either bicellular and panduriform or hammer-shaped or two-armed (*Epithema*, *Klugia*, *Loxonia*, *Napeanthus*, *Rhynchoglossum*) or on the other hand are provided with three or four rays (*Klugia*, *Napeanthus*, *Rhynchoglossum*). The peltate glands of *Monophyllaea Horsfieldii*, R. Br., which were referred to above, belong to a special category; as Fritsch was the first to show, they excrete carbonate of lime. I have examined them and find that their structure corresponds completely with that of the well-known peltate glands of the Rhinanthaceae; the epidermal cell,

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[1] The 'scales' described by Rechinger as occurring on the leaf of *Monophyllaea Horsfieldii*, R. Br. have been shown by Fritsch (loc. cit.) to be small chalk-scales, which are excreted by peculiar glandular hairs functioning as hydathodes (for details regarding the hairs, see the text below). Rechinger's further statement as to the occurrence of small scales in '*Boea speciosa*' still requires reinvestigation.

which constitutes the base of the trichome, is followed by a low middle-cell which has a rounded outline and bears the shield; the latter is of the same size as the middle-cell and is divided into two 'lid-cells' by means of a vertical wall.

For the occurrence of steles in the fibrovascular system of the **petiole** of '*Gesneria alba*,' see Bouygues, loc. cit.

According to my own investigation **medullary vascular bundles** are found both in *Klugia* (*K. ampliata*, Clarke, *K. azurea*, Schlecht., *K. major*, Solered., *K. Notoniana*, Gardn., *K. zeylanica*, Gardn.) and in *Rhynchoglossum* (*R. obliquum*, Bl. with var. *parviflorum*, Clarke), while according to K. Fritsch they occur also in *Monophyllaea Horsfieldii*, R. Br., a species which has only one large foliage-leaf. In *Rhynchoglossum obliquum* (also in the var. *parviflorum*), moreover, a projecting ridge on the stem contains a cortical vascular bundle showing concentric structure.

For the structure of the characteristic runners of *Achimenes coccinea*, which are occupied by scaly leaves, see Kliem, loc. cit.; for the structure of the tubers found in species of *Coleus*, see Chevalier and Perrot, loc. cit.; for the structure of the aerial and terrestrial roots, occurring in species of *Aeschynanthus* and *Columnea*, see Keller, loc. cit. The only feature requiring special mention is the occurrence of medullary vascular bundles showing collateral structure in the tubers of *Coleus langouassiensis*, Chevalier.

Literature: [Pedicino, Sclerenchymi nelle Gesnerac., Rendic. Accad. sc. fis. e mat. Napoli, 1879, fasc. 2; abstr. in Just, 1879, i, p. 24.]—Hassack, Anat. Bau bunter Laubbl., Bot. Centralbl., 1886, iv, p. 84 et seq.—L. Keller, Luftwurzeln, Diss., Heidelberg, 1889, pp. 12–15.—Hallier, in Ann. Jardin Buitenzorg, xiii, 2, 1896, p. 288.—Jönsson, Anat. Bau des Blattes, Acta Univ. Lund., xxxii, 2, 1896, 20 pp.—Rechinger, Trichome der Gesnerac., Österreich. bot. Zeitschr., 1899, p. 89 et seq., sep. copy, 18 pp. and Tab.—Kliem, Vegetat. Regenerationsorg., Diss., Erlangen, 1900, pp. 49, 50.—Bouygues, Pétiole, Thèse, Paris, 1902, p. 78.—Pischinger, *Streptocarpus* and *Monophyllaea*, Sitz.-Ber. Wiener Akad., cxi, Abt. 1, 1902, pp. 287, 291, etc. and Tab. i, ii.—K. Fritsch, Keimpflanzen der Gesnerac., Jena, 1904, especially pp. 132–47.—H. Schmidt, Campanuloideen, Diss., Erlangen, 1904, pp. 101, 102.—Chevalier et Perrot, *Coleus*, in Perrot, Travaux, iii, 1906; also in Végétaux utiles de l'Afrique trop. franç., t. i, 1905, pp. 100–52, pl. 1–8, especially p. 130 et seq.—Solereder, Zur Anatomie u. Systematik einiger Gesneraceen-Gatt., Manuscript, 1907.—[K. Fritsch, in Natürl. Pflanzenfam., Erg.-Heft II, 1908, p. 317.]—K. Fritsch, Cystolithen bei *Klugia zeylanica*, in Wiesner-Festschrift, Vienna, 1908, p. 412.

BIGNONIACEAE (pp. 601–611).

1. To the Review of the Anatomical Features we may add that stomata having two subsidiary cells placed transversely to the pore also occur in this Order (*Kigelia*). Among the list of special features we may include the occurrence of groups of silicified cells in the mesophyll and of solid papillae on the epidermis of the leaf (both features likewise observed in *Kigelia*).

2. Structure of the Leaf. According to my own investigation the **mesophyll** is centric in structure in *Kigelia pinnata*, DC. and *K. africana*, Benth.; it consists of 5 or 6 layers of moderately elongated palisade-cells, the longitudinal walls of which show a bellows-like folding, and at some points include small intercellular spaces between one another after the manner of conjugate parenchyma. Spicular fibres running freely in the mesophyll, besides occurring in *Colea Commersonii* (where they may even spread out beneath both upper and lower epidermis), are found in *Colea pedunculata* (according to Fabricius) and in *Crescentia regalis*, *C. macrophylla* (= *Amphitecna macrophylla*, Miers) and *Phyllarthron comorense*, DC. (according to Cornu). In *Colea pedunculata* there are also scattered stone-cells in the mesophyll. Another noteworthy feature is constituted by spherical or otherwise shaped groups of silicified cells, which were first observed by Cornu in the mesophyll of *Kigelia pinnata*, although his interpretation of them was not quite correct, and which are present also in *K. africana*. Their structure recalls that of the groups of silicified cells, figured for *Aristolochia acutifolia*, Duch. in Fig. 166, G

(on p. 684) in all respects. The constituent cells show an approximately radial arrangement, while those parts of their walls, which are directed towards the centre of the group of cells, and the adjoining parts of the radial walls are thickened in the form of a horseshoe and are stratified and silicified. The groups of cells in question either lie freely in the mesophyll or more commonly occur in connexion with the vascular bundles of the veins, being situated both on their upper and lower side; the number of cells composing the groups varies. In *Kigelia* the upper and lower **epidermis** are likewise silicified; in surface-view the cells of the upper epidermis have undulated lateral walls and, like the epidermal cells situated above the larger veins on the lower side of the leaf, are provided with blunt conical and solid papillae, while the lower epidermis consists almost exclusively of the exceptionally numerous **stomata** with their subsidiary cells. The pairs of guard-cells in *Kigelia* are raised above the surface of the epidermis, and are supported for the most part by two (more rarely by three) neighbouring cells, which are placed transversely to the pore.

The **hairy covering** in *Kigelia* comprises unicellular clothing hairs with rather thick walls and narrow lumina, and relatively large disc-shaped glands showing radial arrangement of the cells and a slight elevation of the cuticle.

3. Structure of the Axis. As regards the occurrence of **anomalous structure** *in the wood of the root in the Bignoniaceae (p. 608) we may note* that according to Hill bast-wedges are found in this position also in *Bignonia unguis* and *B. venusta*.

The **cortex** of *Oroxylum indicum*, Vent. contains deposits of green substances which resemble wax, and are the seat of the active principle (oroxylin) in this bark (O. Werner). It still remains to be determined whether the rubber, which exudes on wounding the cortex in *Stereospermum euphorioides*, is deposited in special receptacles (see Jumelle, loc. cit.).

Literature: [Stowell, Folia Carobae (*Jacaranda Carobae*), Therap. Gazette, N. S., 1881, n. 2, p. 42; abstr. in Just, 1881, ii, p. 691.]—Keller, Luftwurzeln, Diss., Heidelberg, 1889, pp. 15-17.—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Went, Haft- u. Nahrwurzeln, Ann. Jardin Buitenzorg, xii, 1895, pp. 59, 60.—Cornu, *Colea floribunda*, etc., iii and iv, Bull. Soc. bot. de France, 1896, pp. 406-14.—Jonsson, Anat. Bau des Bl., Acta Univ. Lund., xxxii. 2, 1896.—Werner, Neuere Drogen (Cortex Oroxyli), Diss., Erlangen, 1896, pp. 27-33 and Tab. iii, iv.—Hill, Roots of *Bignonia*, Ann. of Bot., 1898, pp. 323-8 and pl. xxii.—Boergesen og Paulsen, Veget. dansk-vestind. Öer, Bot. Tidsskrift, xxii, 1898-9, p. 101 (*Tecoma leucoxylon*, Mart.).—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 27, 28.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 98.—[Anonymous, Glands in *Tecoma*, Gardeners' Chronicle, xxxii, 1902, p. 44.]—Fabricius, Laubblattanatomie, Beih. z. bot. Centralbl., xii, 1902, p. 313 (*Colea pedunculata*).—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 111, 112 and 152-4.—Paoli, Eterofillia, Nuovo Giorn. bot. Ital., N. S., xi, 1904, p. 220 (species of *Bignonia* and *Macrodiscus*).—Frommel, Plantas text. chil., 1905, p. 40.—Jumelle, Une Bignon. à gomme, Comptes rendus Paris, 1905, 1er sém., pp. 170-2.—[Penhallow, Hybridization of *Catalpa*, Americ. Nat., xxxix, 1905, pp. 113-36, abstr. in Bot. Centralbl., cxix, p. 321.]—Piccioli, Legnami, Bull. Siena, 1906, p. 151.—Haberlandt, Sinnesorg., second edition, 1906.—[Schwendt, Extraflor. Nektarien, Beih. z. bot. Centralbl., xxii, Abt. 1, 1907, pp. 256-9.]

PEDALINEAE (pp. 611-613).

Grünewald's paper cited below deals principally with the anatomy of the leaf and axis in the genera *Martynia*, *Craniolaria*, *Pedalium*, *Pterodiscus*, *Harpagophytum*, *Rogeria*, *Sesamum*, *Ceratotheca*, *Pretrea*, and *Josephinia*; it does not contain any essentially new facts.

The characteristic mucilage-hairs appear to occur also in *Pterodiscus* ('*P. angustifolius*'), whilst in *Harpagophytum* the external glands are of the same type as those of *Craniolaria annua*. The structure of the leaf is for the most part bifacial, the stomata generally occurring on both surfaces. In *Craniolaria annua* the epidermis of the leaf contains chlorophyll, and in *Pretrea eriocarpa* and '*Pterodiscus angustifolius*' crystals of oxalate of lime. Oxalate of lime

is occasionally found in the form of crystals resembling raphides (pith of *Rogeria adenophylla*).

As regards the structure of the **axis** it appears that bast-fibres are invariably found in the pericycle, and that the wood-prosenchyma always bears simple pits.

Literature: Grünewald, Vergl. Anat. d. Martyniaceae u. Pedaliaceae, Diss., Erlangen, 1897, 43 pp.

ACANTHACEAE (pp. 613–624).

2. STRUCTURE OF THE LEAF. In the species which have been examined the leaves are for the most part bifacial in structure, rarely (*Acanthopsis horrida*, Nees) centric with palisade tissue on both sides. Friedrich records a papillose **epidermis** in the leaf in *Aphelandra Fascinator*, Lind. et André and *Ruellia Devosiana*, Lindl. According to Holtermann a many-layered hypoderm is found on the upper side of the leaf also in *Strobilanthes sexennis* var. *argutus*. According to Dethan the parenchyma of the veins in *Acanthus mollis*, L. contains membrane-mucilage. At this point we may also mention the occurrence of groups of mucilaginous cells on both sides of the leaf in *Acanthus ilicifolius*, L., a feature which still requires further investigation; on the upper side of the leaf these groups are inserted among the cells of the hypoderm, while on the lower side they are formed mainly by epidermal cells showing palisade-like elongation; in later stages they give rise to organs resembling lenticels (Areschoug).

Oxalate of lime (cf. p. 614) is found in the form of large clustered crystals in *Thunbergia laurifolia*, Lindl. and *Eranthemum igneum*, Lind. (Friedrich). Small crystalline bodies occur very abundantly in the epidermis and in the clothing hairs. The acicular crystals are often differentiated like raphides (see especially A. Weiss, loc. cit.).

To the list of special forms of clothing **hairs** (see p. 614) we may add: (*a*) the unicellular trichomes of *Lasiocladus*, which have thick walls and narrow lumina; (*b*) the uni- or multicellular lanceolate hairs of *Acanthopsis horrida*, Nees, each of which is seated obliquely on an epidermal cell, with the apex of the hair directed towards the tip of the leaf; and (*c*) the trichomes of *Fittonia Verschaffeltii*, which according to Haberlandt function as ocellae; these hairs consist of (1) a large epidermal cell, which has a rounded outline, as seen in surface-view, and projects strongly after the manner of a papilla above the small-celled epidermis, and (2) a very small cell, which is inserted in the apex of the epidermal cell and is shaped like a biconvex lens. The external glands of the second type in some cases have a bicellular head which is divided by a vertical wall, and are sometimes (e.g. in *Ruellia patula*, Jacq. or *Strobilanthes glomeratus*, Anders.) provided with long stalks.

In connexion with the section on the **cystoliths** (see also the table on p. 616) we may first describe the forms of cystoliths recorded by Friedrich in a number of genera not examined by Hobein (*Glossochilus*, *Lasiocladus*, *Petalidium*, *Sautiera*, *Stenostephanus* and *Tetramerium*). *Glossochilus Burchellii*, Nees, which belongs to the Barlerieae, has the double cystoliths characteristic of this group. The genus *Lasiocladus* (*L. acanthospermifolius*, Boj. and *L. chlorotrichos*, Boj.), which Bentham and Hooker place at the end of the Order with the addition of a query, shows affinity with the Barlerieae in having double cystoliths. *Petalidium barlerioides*, Nees and *Sautiera Decaisnei*, Nees (Tribe Ruellieae) have fusiform cystoliths; in *Stenostephanus lobeliaeformis*, Nees (Tribe Justicieae) the cystoliths show a longitudinal arrangement, while the cystoliths in *Tetramerium nervosum*, Nees (Tribe Justicieae) are elongated and either pointed at one end or rounded.

Molisch's recent investigations on the blue-green colouration of the cystoliths, previously observed by K. Richter and A. Weiss in species of *Goldfussia* and *Sanchezia*, necessitate the addition of the following details. The lithocysts of *Sanchezia nobilis*, Hook., *Strobilanthes Dyerianus*, Hort. and *Goldfussia anisophylla*, Nees contain a colourless chromogen (pseudo-indican) which, on coming in contact with the air as the result of injury to the cells containing it, gives rise to a deep blue-green colouring-matter which appears on the surface of the body of the cystoliths or in their immediate neighbourhood. On the other hand, the greenish coloration shown by the cystoliths of *Ruellia ochroleuca*, when seen in sections, is due to the anthocyanin contained in the surrounding cells, the violet colour of the anthocyanin changing to green in contact with the cystoliths owing to their alkaline reaction.

Dethan and Friedrich have recently demonstrated **acicular fibres** (raphidines, see p. 618) in a large number of additional genera and species.

These species are as follows: *Acanthopsis horrida*, Nees, *Andrographis paniculata*, Nees, *Anisacanthus virgularis*, Nees, *Aphelandra aurantiaca*, Nees and *A. Fascinator*, Lind. et André, *Barleria cristata*, L. and *B. Prionotis*, L., *Crossandra infundibuliformis*, Nees and *C. undulaefolia*, Salisb., *Cystacanthus turgida*, Nichols., *Dianthera pectoralis*, Gmel., *Dicliptera acuminata*, Juss., *Ecbolium Linneanum*, Kurz, *Eranthemum sanguinolentum*, Veitch, *Fittonia argyroneura*, Coëm., *Justicia carnea*, Lindl. and *J. Gendarussa*, Burm., *Peristrophe bicalyculata*, Nees, *Rhinacanthus communis*, Nees, *Ruellia formosa*, Andr. (*Arrhostoxylum formosum*, Nees), *Sanchezia nobilis*, Hook. f., *Sautiera Decaisnei*, Nees.

For the occurrence of steles in the **petiole** of *Acanthus mollis*, see Bouygues, loc. cit.

3. Structure of the Axis. Dethan has recently examined the structure of the cortex in certain officinal species. The cork develops in the epidermis in *Strobilanthes callosus*, Nees, and in the subepidermal layer of cells in *Crossandra undulaefolia*, Salisb. and *Jacobinia Mohintli*, Benth. et Hook. The outer portion of the primary cortex is frequently differentiated as collenchyma. In *Strobilanthes callosus*, Nees there is a complete subepidermal layer of lithocysts. The occurrence of fibrous cells in the collenchyma of the primary cortex in *Nelsonia campestris*, R. Br. and *Thyrsacanthus nitidus*, Nees recalls the hypoderm of fibrous cells characteristic of *Thunbergia*. Stone-cells or slightly sclerosed parenchymatous cells have been observed in the primary cortex in *Dianthera pectoralis*, Gmel., *Jacobinia Mohintli*, Benth. et Hook., *Justicia Gendarussa*, Burm. and *Strobilanthes callosus*, Nees. The species of *Hygrophila* are distinguished by having a lacunar cortex with wide intercellular spaces. In *H. spinosa*, Anders. the walls of the meshes are formed by cells having a particularly characteristic shape, which in a transverse section of the branch resembles that of a thigh-bone, while in the corners of the meshes the cells are generally three-armed and likewise have swollen ends; these cells, moreover, are dovetailed with one another by means of the undulated surfaces of their walls. In most of the species the pericycle contains isolated bast-fibres or groups of bast-fibres, but occasionally primary hard bast is absent. In the latter case a distinct endodermis is sometimes (*Barleria cristata*, L.) present. Bast-fibres and acicular fibres are of frequent occurrence in the secondary bast.

As regards the occurrence of **anomalous structure** in the axis (p. 620) we may note that Dethan's statement as to the presence of intraxylary phloem in *Justicia Gendarussa*, Burm. is incorrect, and that, according to Leisering, in the formation of the interxylary phloem in *Thunbergia coccinea*, Nees, at least, the cambium at first develops nothing but thin-walled parenchyma on its inner side, sieve-tubes only becoming differentiated in this parenchyma in later stages.

For the structure of the terrestrial **roots** of *Acanthus ilicifolius* (occurrence of peculiar thickening-plates, traversed by slit-shaped pits, in the cortical parenchyma), see Karsten, loc. cit.

Literature: A. Weiss, Kalkoxalatm. in Acanthac., Sitz.-Ber. Wiener Akad., xc, Abt. 1, 1884, pp. 79–90 and Tab.—Gardiner, Secret. hairs of *Thunbergia laurifolia*, Proceed. Cambridge Phil. Soc., v, 1884, pp. 184, and 1887, p. 82.—Karsten, Mangrovevegetat., Bibl. bot., Heft 22, 1891, p. 50.—Dethan, Acanthacées méd., Thèse, Paris, 1896 (2e éd., 1897), 192 pp.[1]—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 39–44.—Molisch, Pseudoindican. Sitz.-Ber. Wiener Akad., cviii, Abt. 1, 1899, pp. 479–90 and Tab.—Friedrich, Blattanatomie der Acanthac., Diss., Heidelberg, 1901, 62 pp., 1 Tab.[2]—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 73.—Areschoug, Mangrovepfl., Bibl. bot., Heft 56, 1902, pp. 48–50 and Tab. v (*Acanthus ilicifolius*, L.).—Bouygues, Pétiole, Thèse, Paris, 1902, p. 79.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 10, 11 (*Adhatoda*).—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 159, etc.—Viret, Liaisons du phloème méd., etc., Institut de Bot. Genève, 1904, pp. 71–96 (*Acanthus* and *Thunbergia*).—Haberlandt, Lichtsinnesorgane, 1905, pp. 107–11 and Tab. iii.—Holm, in Americ. Journ. of Pharm., 1906, p. 553 et seq., and 1907, p. 51 et seq. (*Ruellia ciliosa*).—Holtermann, Einfluss d. Klimas, 1907, p. 216.—[Holm, *Ruellia* and *Dianthera*, Bot. Gazette, xliii, 1907, pp. 308–29 and pl. xi–xiii.]

MYOPORINEAE (pp. 624–628).

Literature: Boergesen og Paulsen, Veget. dansk-vestind. Öer, Bot. Tidsskrift, xxii, 1898–9, pp. 21–3 (*Bontia daphnoides*, L.).

SELAGINEAE (pp. 628–630).

The epidermis of the leaf of *Globularia salicina*, Lam. consists locally of two layers.

Literature: Latour, Séné, Thèse, Montpellier, 1894, pp. 36–40 (*Globularia*, *Alypum*).—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 9, 10 (*Globularia salicina*, Lam., sphalm. *salicifolia*).

VERBENACEAE (pp. 630–636).

1. Review of the Anatomical Features. In the genera *Symphorema* and *Congea* (Symphoremeae) large secretory cells occur in the bast and primary cortex of the branches. *Teijsmanniodendron* has large solitary and clustered crystals, as well as medullary 'bundles of mestome.' Tufted hairs are also found in *Symphorema*.

2. Structure of the Leaf. Van Tieghem has recently undertaken a detailed examination of the structure of both leaf and axis (see below) in the Symphoremeae and Avicennieae. The following details are abstracted from his investigations and the remaining new literature. According to Areschoug **stomata** with two subsidiary cells placed transversely to the pore are found in *Avicennia nitida*, Jacq.; stomata having three neighbouring cells occur in *Teijsmanniodendron bogoriense*, Koord., and stomata with several ordinary neighbouring cells in *Lippia Geisseana*, Solered. According to Van Tieghem the many-layered hypoderm found in *Avicennia* occupies half the thickness of the leaf in *A. officinalis*, while it is not so thick in the two species *A. nitidus* and *A. tomentosus*, which are grouped in the subgenus *Hilairanthus*.

[1] This paper deals with species of the following genera: *Acanthus*, *Adhatoda*, *Andrographis*, *Barleria*, *Blepharis*, *Cystacanthus*, *Dianthera*, *Dicliptera*, *Ecbolium*, *Graptophyllum*, *Hygrophila*, *Jacobinia*, *Justicia*, *Nelsonia*, *Rhinacanthus*, *Ruellia*, *Rungia*, *Strobilanthes*, *Thunbergia*, *Thyrsacanthus*.

[2] This investigation deals with species of *Acanthopsis*, *Acanthus*, *Adhatoda*, *Anisacanthus*, *Aphelandra*, *Barleria*, *Blepharis*, *Crossandra*, *Dianthera*, *Dicliptera*, *Eranthemum*, *Fittonia*, *Geissomeria*, *Glossochilus*, *Gymnostachyum*, *Hemigraphis*, *Hypoëstes*, *Justicia*, *Lasiocladus*, *Libonia*, *Peristrophe*, *Petalidium*, *Rhinacanthus*, *Ruellia*, *Rungia*, *Sanchezia*, *Sautiera*, *Stenandrium*, *Stenostephanus*, *Strobilanthes*, *Tetramerium*, *Thunbergia*.

Three vascular bundles enter the leaf in *Avicennia*, as well as in *Symphorema* and *Congea*. In the petiole of *Avicennia* they form a median bundle, which is closed in an annular manner, and a few small cortical bundles, while in the petiole of *Symphorema* and *Congea* they give rise to a large arc of wood and bast.

In view of the earlier statement as to the absence of **internal glands** the demonstration of large secretory cells in the bast and primary cortex of the branches in *Symphorema* and *Congea* (but not in *Sphenodesma*) by Van Tieghem is very noteworthy. In *Lippia Geisseana* and (according to Quanjer) also in *Vitex trifolia*, L. **oxalate of lime** is found in the mesophyll in the form of small clustered crystals, whilst *Teijsmanniodendron bogoriense* has large solitary crystals in the cortical parenchyma and clustered crystals in the tissue of the pith. Regarding the occurrence of sphaerocrystalline masses in the epidermis of the leaf in species of *Campylostachys*, see Knoblauch, loc. cit.

With reference to the **hairy covering** of the Verbenaceae (p. 631 et seq.) we may add the following details. Uniseriate clothing hairs are found also in *Congea tomentosa*, Roxb., while tufted hairs with unicellular rays occur in *Symphorema involucratum*, Roxb. According to Haberlandt the small silicified trichomes inserted in the outer walls of the epidermal cells in *Petraea volubilis* (Fig. 151, *A–B*) are local organs for the perception of light; to judge from Koorders' statements similar trichomes appear to occur also in *Teijsmanniodendron*. Unicellular cystolith-hairs which have calcified tips and in part contain cystolith-like protuberances (the latter occasionally occurring in the subsidiary cells of the hairs as well) are present also in *Lippia Geisseana*. Glandular hairs with unicellular heads are found also in *Lippa* (*L. Geisseana*, *L. saturejaefolia*, Mart. et Schauer, *L. thymoides*, Mart. et Schauer) and in *Lantana macrophylla*, Schauer and *L. involucrata*, L.; peltate glandular hairs, like those of *Avicennia*, &c., occur also in *Citharexylum cinereum*, L., and vesicular integumental glands resembling those of the Labiatae also in *Vitex trifolia*, L. The glandular hairs found on the parts of the flower occasionally differ from those present on the vegetative organs. Thus on the bracts of *Lippia Geisseana* the heads of the glands are both unicellular and composed of a small number of cells owing to vertical division-walls, whilst on the clavate processes of the anthers they show a still larger number of vertical division-walls. An even more striking feature lies in the occurrence of external glands with elongated ellipsoidal or tubular heads divided both by horizontal and vertical walls on the processes of the anthers in *Tamonea spicata*, Aubl. and on the connectives of the anthers in *Casselia integrifolia*, Nees et Mart. We must regard these external glands as forming exceptions to the general rule, since the glands of the Verbenaceae in most cases have heads, which are either unicellular or divided exclusively by vertical walls (see Solereder, loc. cit., p. 627, footnote 1).

3. Structure of the Axis. For the structure of the stem in *Lippia Geisseana*, a Chilian desert-plant (having radial plates of sclerenchymatous fibres corresponding in position with the ribs on the stem and palisade tissue in the outer part of the cortex, &c.), see Solereder, loc. cit.

The **cork** develops in the subepidermal layer of cells also in *Avicennia*, *Symphorema* and *Congea*. In the species of *Symphorema* and *Congea* mentioned above the **pericycle** contains an annular zone of lignified fibres, while in *Sphenodesma unguiculata*, Schauer it includes a composite and continuous ring of sclerenchyma. In *Symphorema involucratum* the secondary bast contains stone-cells, and in *Sphenodesma unguiculata*, Schauer bands of sclerosed cells. Pitard records isolated bundles of bast-fibres in the pericycle in species of *Aegiphila*, *Clerodendron*, *Cornutia*, *Oxera*, and *Verbena*, and a composite and interrupted ring of sclerenchyma in the pericycle in *Clerodendron aculea-*

tum, *C. Bungei*, and *Vitex agnus-castus*. The vessels have scalariform perforations also in *Teijsmanniodendron* (Koorders).

The **medullary mestome-bundles** mentioned above as occurring in *Teijsmanniodendron* are present in large numbers (about 25) and consist of libriform and wood-parenchyma.

Note. For the anatomy of the aerial and terrestrial **roots** of *Avicennia tomentosa*, see also W. Brenner, loc. cit.; regarding *Avicennia nitida*, Jacq., see Boergesen and Paulsen, loc. cit.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 123.—Karsten, Mangrove-Vegetat., Bibl. bot., Heft 22, 1891, p. 50.—Knoblauch, Ökolog. Anat., etc., Habilitat.-Schr., Tübingen, 1896, p. 8 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 20.—Solereder, *Buddleia Geisseana*, Bull. Herbier Boissier, 1898, pp. 623–9.—Van Tieghem, Avicenniacées et Symphorémacées, Journ. de Bot., 1898, pp. 345–65.—Boergesen og Paulsen, Veget. dansk-vestind. Öer, Bot. Tidsskr., xxii, 1898–9, pp. 37–9 (*Avicennia nitida*, Jacq.), p. 100 (*Citharexylum cinereum*, L.) and p. 90 et seq. (*Lantana*).—Kearny, in Contribut. U. S. Nat. Herb., v, n. 5, 1900, p. 304 (*Lippia nodiflora*).—Thomas, Feuilles sout., Thèse, Paris, 1900.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 88.—Areschoug, Mangrovepfl., Bibl. bot., Heft 56, 1902, pp. 50–2 and Tab. iv and vii (*Avicennia nitida*).—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 565 (Viteae).—Penzig, Piante acarofile, Malpighia, 1902, p. 451 (*Citharexylum*).—W. Brenner, Luftwurzeln von *Avicennia tomentosa*, Ber. deutsch. bot. Gesellsch., 1902, pp. 175–88 and Tab. vi–viii.—Quanjer, Anatomisch Bouw, etc., Natuurkund. Verbandel. Haarlem, iii, 5, 1903 (*Vitex trifolia*).—Theorin, Vaxttrichom., Arkiv för Bot., i, 1903, p. 156.—Ursprung, Dickenwachstum, Bot. Zeit., 1904, p. 192 et seq. (*Tectona grandis*, L.).—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 118, 119.—Koorders, *Teijsmanniodendron*, Ann. Jardin Buitenzorg, xix, 1904, pp. 22, 23.—Haberlandt, Lichtsinnesorgane, 1905, pp. 73–5 and Tab. ii.—Piccioli, Legnami, Bull. Siena, 1906, p. 150.—Holtermann, Einfluss des Klimas, 1907, pp. 31, 59 and 212.

LABIATAE (pp. 636–642).

1. Review of the Anatomical Features. To the list of special features we may add the occurrence of characteristic secretory cells in the mesophyll of *Pogostemon*; these cells are differentiated as internal (glandular) hairs, being provided with a stalk composed of a small number of cells and a unicellular vesicular and glandular head of varying shape.

2. Structure of the Leaf. To p. 637 et seq. the following details may be added. Small clustered crystals of oxalate of lime have recently been recorded also by Clauditz in *Salvia canariensis*, L. A noteworthy feature from the systematic point of view is the occurrence of a special body in the form of Molisch's **scutellarin** in all the species of *Scutellaria* which have been examined, as well as in *Galeopsis Tetrahit*, L. and *Teucrium Chamaedrys*, L., while the investigation of certain species of *Ballota*, *Brunella*, *Glechoma*, *Lamium*, *Leonurus*, *Mentha*, *Nepeta*, *Teucrium*, and *Thymus* gave a negative result; the chemical composition of this body has been examined in detail by Goldschmiedt. The chief seat of the scutellarin is in the epidermis of the leaf and especially in the lower epidermis. On treating sections with a 10 % solution of hydrochloric acid the scutellarin crystallizes out in the form of sphaerites or of needles, which are grouped in a tufted or stellate manner. Regarding the occurrence of masses, which resemble sphaerites and show similarity with hesperidin, in the mesophyll of *Hyssopus officinalis*, see Tunmann, loc. cit. I observed the above-mentioned **secretory cells**, which are differentiated as internal glandular hairs, in the Patchouli-drug, which is derived from the leaves of *Pogostemon Patchouli*, Pellet, as well as in the cortical tissues of the same plant. In the leaf these secretory cells belong to the mesophyll; they are intercalated between the cells of the palisade and spongy tissues, frequently projecting into the intercellular spaces. They have a short stalk, which is composed for the most part of two or three low cells with suberized walls and forms the means of attachment to the cells of the

mesophyll, and a variously shaped unicellular head: the latter is either sac-shaped or lobed, and shows a cuticularized membrane, which is raised above the cellulose-membrane like a bladder, in the same way as in the rather large vesicular integumental glands with a unicellular head found on the surface of the leaf; the resinous or oily secretion is soluble in alcohol and fills both the space between the cellulose- and suberized membranes and the lumen of the head-cell.

Clauditz has demonstrated branched **hairs** also in *Sideritis* (*Leucophae*, Webb). The vesicular integumental glands in some cases (*Pogostemon*) merely have a relatively large unicellular head.

For the occurrence of steles in the **petiole** of *Phlomis Russeliana*, see Bouygues, loc. cit.

Literature. Paschkis, Minder bek. Blatter, Zeitschr. osterreich. Apotheker-Ver., 1879, p. 415 et seq. (*Pogostemon*).—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 113 et seq. —Costantin, Tiges d. pl. aquat., Ann. sc. nat., sér. 6, t. xix, 1884, p. 287 et seq. and pl. xv.—Jost, Zerklüftung einig. Rhiz. u. Wurz., Bot. Zeit., 1890, p. 501 (*Salvia*).—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Spanjer, Wasserapparate, Bot. Zeit., 1898, i, p. 50.—Hirsch, Entwickl. d. Haare, Diss., Berlin, 1899, p. 19 et seq.—Kearny, in Contrib. U. S. Nat. Herb., v, n. 5, 1900, p. 297 (*Teucrium Nashii*, Kearny).—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 38-43.—Molisch u. Goldschmiedt, Scutellarin, Sitz.-Ber. Wiener Akad., cx, Abt. 1, 1901, especially pp. 185-9.—Petersen, Vedanatomi, 1901, p. 84.—Pitard, Péricycle, These, Bordeaux, 1901, p. 38.—Bouygues, Pétiole, These, Paris, 1902, p. 75.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 16, 17 and 48, 49 (*Leucophae*, *Micromeria*, *Salvia*).—[Armari, Piante della reg. medit., Ann. di. Bot., i, 1903, p. 17 et seq. (*Phlomis*, *Thymus*).]—Theorin, Vaxttrichom., Arkiv for Bot., i, 1903, p. 156.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 118.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 69-71.—Sussenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Wurzburg, 1904, pp. 47-50.—Sarton, Anat. d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 79-85, 86-93, 101-104 (*Ajuga*, *Calamintha*, *Galeopsis*, *Lavandula*, *Teucrium*).—Dauphiné, Rhizomes, Ann. sc. nat., sér. 9, t. iii, 1906, pp. 360 and 362 et seq.—Piccioli, Legnami, Bull. Siena, 1906, p. 141.—[Tunmann, *Hyssopus officinalis*, Zeitschr. allg. österreich. Apoth.-Ver., 1906, n. 30-32; abstr. in Bot. Centralbl., civ, p. 63.]—[Borde, Rech. histochim. sur les Labiées astringentes, Toulouse, 1907.]—Solereder, Die inneren haarart. Sekretdrüsen des Patschuliblattes, Archiv d. Pharm., 245, 1907, pp. 406-9.—[For further literature, see p. 1170.]

PLANTAGINEAE (pp. 642–644).

In the first place we may add the following details to the section dealing with The Structure of the Leaf on the basis of Pilger's recent investigations on the anatomy of the species of *Plantago*. The leaves are for the most part centric in structure; they either have palisade tissue on both sides and spongy tissue in the middle, or the mesophyll consists of palisade tissue only; in many cases, moreover, it is homogeneous, being composed of uniform assimilatory tissue with rounded cells. In all the species the stomata are situated on both surfaces of the leaf. The vascular bundles of the **veins** are invariably provided with sclerenchymatous layers on their upper and lower side or are surrounded by a ring of sclerenchyma; in their course through the petiole they are distinct from one another. A type of clothing **hair**, which is specially noteworthy from the systematic point of view, is constituted by trichomes having a short stalk-cell, which is seated on an epidermal cell as base, and a long flagelliform terminal cell with thick walls. These clothing hairs, which have already previously been recorded in *Plantago arctica*, are characteristic of the perennial species of the section *Oreades*, Decne., and of the species of the sections *Arnoglossum*, Decne. and *Leucopsyllium*, Decne. The flagelliform trichomes of *Plantago Bismarckii*, Niederl. (section *Bismarckiophyton*, Harms) differ to a slight extent in the fact that the basal cell, which projects above the level of the leaf, is divided by a wall running parallel to the surface. Another type of trichome is found in the species of the subgenus *Psyllium*, Harms (e.g. *Plantago mauritanica*) in the form of papillose hairs; these consist of a large thick-walled cell, which is seated on several epidermal cells and is

arched outwards. Glandular hairs occur only in species of the subgenus *Psyllium*, Harms. Pilger remarks upon them as follows: 'One finds either multicellular sessile glands, or a multicellular head inserted on a delicate unicellular stalk, or a unicellular head on a multicellular stalk; in the latter case one or two of the cells below the head have thin walls, while the epidermal cell and the first few cells of the hair are broadened and have thickened walls.'

As regards THE AXIS of the genus *Plantago* (p. 644) we may note in the first place that certain differences in structure go hand in hand with the varied morphological nature of the stem, which is differentiated either as a rhizome or as a subaerial axis. The earlier statement as to the absence of **medullary rays** must be limited in the sense that there are no secondary medullary rays. The xylem-ring shows interruptions, which are of primary origin (primary medullary rays), although they are not to be found in every transverse section; the parenchyma composing these rays, or at least some of it, often becomes lignified. In the annual species belonging to the subgenus *Psyllium* a typical multiseriate ring of bast-fibres is generally developed in the **pericycle** on the inner side of the endodermis, which is devoid of chlorophyll; to judge by Reiche's statements the same is the case in *Plantago Fernandezia*, Bert. In other cases typical hard bast appears to be wanting, and it is only in certain species of the section *Leucopsyllium* (e.g. *Plantago albicans*), in *Plantago Bismarckii*, Niederl., *P. princeps*, Cham. et Schlecht. and in certain shrubby species of the subgenus *Psyllium* (e.g. *Plantago sinaica*, Barn.) that one meets with sclerenchymatous elements at the outer limit of the bast; these elements are probably for the most part parenchymatous, being differentiated from the outermost portion of the soft bast. In those species, which have a thick mass of wood, the phloem is feebly developed. In the fleshy rhizomes there are long rows of cambiform cells, the outer layers of which show collenchymatous thickening. The tissue of the **pith** either persists as thin-walled parenchyma or (in the shrubby species) becomes lignified; the cells occasionally bear large pits. **Medullary cambiform-bundles** occur chiefly in the fleshy rhizomes of the species belonging to the section *Polyneuron*, Decne. (exceptions: *Plantago palmata*, *P. cordata*, Lam., &c.), although they are sometimes found also in species of the section *Heptaneuron*, Decne., and in *Plantago princeps*, Cham. et Schlecht., which together with *P. Fernandezia*, Bert. (which is distinguished by having medullary and cortical bundles, see p. 644) constitutes the section *Dendriopsyllium*, Decne. In *Plantago Cornuti*, Gouan there are all transitions between these medullary bundles and true vascular bundles; the latter are recorded by Pilger also in *P. princeps*. Groups of stone-cells are found in the pith of the fleshy rhizomes of species belonging to the section *Oreades*, Decne. and in the pith and primary cortex of the fleshy rhizomes of species of the section *Arnoglossum*, Decne. (also in the annual species *Plantago Lagopus*, *P. lusitanica*, Willd., &c.).

We may finally mention a phenomenon, which has been observed in a few species of the section *Oreades* (e.g. *Plantago saxatilis*, Bieberst.) and in *Plantago alpina*, L. (section *Coronopus*, Decne.); in these forms the rhizome splits up into several large bundles owing to the formation of medullary cork, which enters into connexion with the outer periderm by way of the primary medullary rays (for details, see Pilger, loc. cit.). We may also add a statement of Reiche, which was overlooked in the earlier part of this work, and according to which abundant 'crystals' are present in the pith of *Plantago Fernandezia*.

The flowering scapes of *Plantago* show a more or less developed ring of bast-fibres adjoining the ring of vascular bundles, while on the outer side of the ring of fibres there is an endodermis which does not contain any chlorophyll. Numerous strands of sieve-tubes are found between the vascular bundles being situated at the limit of the pith and the ring of bast-fibres.

Literature: Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 124 et seq.—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, p. 62.—Pilger, Vergl. Anat. d. Gatt. *Plantago*, in Engler, Bot. Jahrb., xxv, 1898, pp. 296–351.—Minden, Wassersec. Org., Bibl. bot., Heft 46, 1899, p. 18 (*Littorella*).—Swanlund, Vegetat. Neu-Amsterdams u. St. Pauls, Diss., Basel, 1901, pp. 26–9 (*Plantago Stauntoni*, Reichenb.[1]).

NYCTAGINEAE (pp. 645–649).

2. Structure of the Leaf. The following details are taken from Heimerl's and Gidon's recent investigations. The leaves show centric structure, for example, in *Bougainvillea patagonica*, Decne., *Phaeoptilon spinosum*, Radlk. and *Abromia umbellata*, Lam. In *Boerhaavia viscosa*, Lag. et Rodr. the cells of the palisade tissue are provided with short processes, which are sharply demarcated from the cell proper and form the means of connexion between the cells; similar short processes are found also on the cells of the spongy tissue in this species, and altogether appear to be of rather frequent occurrence on the cells of the leaf-tissue in the Nyctagineae (*Bougainvillea spectabilis*, Willd., *Oxybaphus viscosus*, L'Hérit., &c.). In *Boerhaavia viscosa* the vascular bundles of the smaller veins are surrounded by a sheath of large parenchymatous cells, which is only interrupted opposite the bast, while the sheaths of the larger veins are less complete; a weakly developed sheath of large parenchymatous cells has been recorded also in *Bougainvillea spectabilis*, and a distinctly differentiated sheath in *Phaeoptilum spinosum*. In *Bougainvillea patagonica*, *Boerhaavia viscosa* and *Phaeoptilum spinosum* the stomata are found on both surfaces of the leaf. The last of these species has a hypoderm of large cells with rather thick walls beneath the epidermis. According to Heimerl uniseriate trichomes with a swollen, vesicular terminal cell, which has a rather thick stratified wall, so that the amount of secretion is insignificant, are very widely distributed in the species of *Bougainvillea*. The same author also records small uniseriate trichomes with a few short stalk-cells and a clavate or vesicular terminal cell, which sometimes has thick stratified walls, in *Bougainvillea patagonica*; these hairs occasionally bear lateral vesicular cells in addition to the terminal one, and thus approximate to the branched hairs with a glandular function, previously described in *Pisonia tomentosa* (see Fig. 154, *B*, p. 646). The deposits of oxalate of lime in this Order appear not uncommonly to assume diverse crystalline forms in one and the same organ (see the earlier statements regarding *Pisonia nitida*). In species of *Bougainvillea* Heimerl observed the following types occurring side by side: raphide-sacs of varied size and differentiation, short sacs containing a large number of delicate needles, sacs with distinct prismatic crystals, &c. In the veins of the leaf of *Phaeoptilum spinosum* short prismatic crystals are found side by side with bundles of raphides. Elongated styloids, traversing the mesophyll at right angles to the surface of the leaf, are characteristic of *Bougainvillea modesta*, Heimerl, and *B. stipitata*, Griseb.

For the arrangement of the vascular bundles in the median vein and their course, see Gidon, loc. cit.

Literature: [Ormandy, Schlauchgef. v. *Mirabilis*, Koloszvar, 1881, 31 pp. (Hungarian).]—Gidon, Appareil conducteur dans la tige et dans la feuille des Nyctagin., Thèse, Caen, 1900, 120 pp., pl. i–vi; see also Mém. Soc. Linn. de Normandie, xx. 1900.—Heimerl, Monogr. d. Nyctagin., 1 (*Bougainvillea*, *Phaeoptilum*, *Colignonia*), Denkschr. Wiener Akad., lxx, 1901, p. 97 et seq.—[Riessner, Beitr. z. Anat. d. Bl. mancher Nyctagin., Societas historico-naturalis croatica, xii, 1901, pp. 1–24, 3 Tab. (Croatian); abstr. in Bot. Centralbl., lxxxix, pp. 146 and 357.]

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[1] The statements in this paper as to the occurrence of crystals of carbonate of lime in the axis of the inflorescence and in the mesophyll are no doubt incorrect.

ILLECEBRACEAE (pp. 649–651).

To the first paragraph which summarizes the ANATOMICAL FEATURES OF THE ORDER we may add the following details. Pericyclic development of the cork has been observed in the axis of *Gymnocarpos*, *Habrosia*, and *Scleranthus*. Stomata conforming to the Caryophylleous type occur also in *Habrosia*. Branched hairs are found also in *Achyronychia*, and uniseriate glandular hairs with a unicellular head also in *Habrosia*. Masses of crystal-sand, similar to those found in *Gymnocarpos*, are present also in *Habrosia* and *Dysphania*. Lastly, anomalous structure of the vascular system (successive rings of growth) has been observed also in the axis of *Cometes*, and in the root in species of *Acanthonychia* (*Pentacaena*), *Achyronychia*, *Cometes*, *Corrigiola*, *Dysphania*, *Haya*, and *Pollichia*.

The STRUCTURE OF THE LEAF (as well as that of the axis) has recently been examined especially by Jösting and Lüders, their investigations dealing with species of *Illecebrum*, *Acanthonychia* (*Pentacaena*), *Dysphania*, *Pollichia*, *Haya*, *Achyronychia*, *Paronychia*, *Herniaria*, *Siphonychia*, *Anychia*, *Corrigiola*, *Gymnocarpos*, *Sclerocephalus*, *Pteranthus*, *Cometes*, *Dicheranthus*, *Scleranthus* and *Habrosia*. The structure of the leaf is centric, more rarely (*Siphonychia*) bifacial; according to Jösting distinct palisade tissue is more commonly developed than Lüders' recent statements lead one to suppose. **Stomata** of the Caryophylleous type are found also in *Habrosia spinuliflora*, Fenzl, while in *Siphonychia americana*, Torr. only some of the stomata are surrounded by distinct subsidiary cells of relatively small size. In the remaining members of the Order subsidiary cells are wanting. In *Habrosia spinuliflora* the stomata on the leaf show the same arrangement as in *Scleranthus*; the same feature has been observed also in *Anychia dichotoma*, Michx. and *Gymnocarpos fruticosum*, Pers. (= *G. decandrum*, Forsk.). Deeply sunk stomata are found also in *Pteranthus echinatus*. In the species examined by Lüders the stomata are always present on both surfaces of the leaf. The **epidermal cells** in the species investigated by Jösting are of large size in all the members of the Tribes Pollichieae and Paronychieae (with the exception of *Paronychia serpyllifolia*, DC. and *Herniaria glabra*, L.), as well as in *Cometes abyssinica*, R. Br.; *Pteranthus echinatus* has high epidermal cells, whilst the cells of the epidermis are unusually large in *Habrosia spinuliflora* and *Scleranthus perennis*, L. Strong punctation of the cuticle is characteristic of *Illecebrum* (Lüders), while in other cases a slight punctation or striation may be observed. Papillae are found at the margin of the leaf and beneath the veins in species of the genera *Achyronychia*, *Anychia*, *Cometes*, *Corrigiola*, *Habrosia*, *Pollichia* and *Scleranthus*. In *Cometes abyssinica*, *Dicheranthus plocamoides*, Webb, and *Pteranthus echinatus* the epidermis is covered by a thick deposit of wax. The vascular bundles of the **veins** are occasionally accompanied by sclerenchyma (species of *Acanthonychia*, *Habrosia*, *Paronychia*, *Pollichia*, *Scleranthus*, &c.).

Unicellular clothing **hairs** have been observed also in *Siphonychia*, and uniseriate hairs also in *Habrosia*; transitional forms between unicellular trichomes and richly branched multicellular hairs have been found in *Achyronychia Parryi*, Hemsl. The different parts of the stem in *Cometes abyssinica* bear peculiar uniseriate trichomes, consisting of a large and broad barrel-shaped basal cell, followed by four further cells, which show a successive decrease in size, and ending in a pyriform terminal cell; the trichomes found on the surface of the leaf, on the other hand, are reduced to the pyriform cells, which bear scattered grains of wax. Glandular hairs with a uniseriate stalk and a unicellular spherical secretory head are present also in *Habrosia spinuliflora*. Clustered **crystals of oxalate of lime** are widely distributed both in the leaf

and axis. A feature deserving mention is the occurrence of rows of clustered crystals at the margin of the leaf in ***Anychia dichotoma***, Michx. and ***Habrosia spinuliflora***. The characteristic masses of crystal-sand have also been found by Jösting in ***Habrosia spinuliflora*** (in the axis and leaf) and by Lüders in ***Dysphania***.

We may now consider the Structure of the Axis. In most of the species the vascular bundles unite to form a ring, but in ***Corrigiola capensis***, Willd. the transverse section of the stem shows six isolated bundles, which are alternately large and small and are arranged in a single ring. As regards the structure of the **wood** we may first note that Jösting likewise failed to observe typical medullary rays in any of the species. The vessels invariably have simple perforations. In almost all the members of the Pollichieae, Paronychieae and Scleranthеae, which have been examined, the wood-prosenchyma bears bordered pits; the only exceptions are ***Herniaria glabra***, L., in which Jösting did not find any lignified wood-fibres whatsoever, and *Achyronychia Parryi*, Hemsl., in which the wood-fibres are not pitted. The relative numbers of vessels and wood-fibres participating in the formation of the wood are subject to variation. An endodermis composed of large cells is developed in very many members of the Order. The sclerenchyma in the **pericycle** for the most part forms a closed strengthening ring consisting of from one to five layers of fibrous cells; in the thicker parts of the axis this ring may become burst open. In *Corrigiola capensis* the pericycle contains isolated groups of fibres only, while in *Pteranthus echinatus* the gaps in the sclerenchymatous pericycle are closed by sclerosed parenchyma. On the inner side of the pericyclic sclerenchyma one occasionally meets with parenchymatous tissue belonging to the pericycle, and in ***Illecebrum verticillatum***, L. this tissue consists of remarkably large cells; within the parenchymatous pericycle lies the soft bast, which shows collenchymatous differentiation in many of the species. Subepidermal development of the **cork** has been observed also in *Anychia* (according to Regnault), *Herniaria glabra* and *Paronychia serpyllifolia*, while the origin of the cork is pericyclic in *Gymnocarpos fruticosum*, *Habrosia spinuliflora* and *Scleranthus perennis*. In many members of the Order there is a cavity in the **pith**.

Anomalous structure of the vascular system, consisting in the formation of concentric rings of vascular bundles, is found also in the axis of *Cometes* (according to Lüders), in the root of *Achyronychia Parryi*, A. Gray, *Corrigiola capensis*, Willd. and ***Pollichia campestris***, Sol. (according to Jösting), and in the more strongly developed roots of certain unnamed species of *Acanthonychia* (***Pentacaena***), *Cometes*, ***Dysphania*** and ***Haya*** (according to Lüders).

Literature: Christ, Laubblattstengel der Caryophyllinen u. Saxifrageen, Diss., Marburg, 1887, pp. 60–8.—W. Meyer, Beitr. z. vergl. Anat. d. Caryophyllaceen u. Primulaceen, Diss., Göttingen, 1899, pp. 39–41.—[Parmentier, Gnavelles de France, Ann. Soc. bot. Lyon, xxiv, 1899, p. 83 (*Scleranthus*).]—Jösting, Anat. d. Sperguleen, Polycarpeen, Paronychieen, Sclerantheen u. Pterantheen, Beih. z. Bot. Centralbl., xii, 1902, pp. 149–56, 159–62, 163 and 171 et seq., also Tab. ii [or 4].—H. Lüders, Untersuch. über d. Caryophyllaceen mit einfachem Diagramm, Diss., Erlangen, 1906, pp. 33–8; sep. copy from Engler, Bot. Jahrb., xl.

AMARANTACEAE (pp. 651–655).

2. Structure of the Leaf. Capitate hairs with a uniseriate stalk composed of a small number of cells and a tubular unicellular head are found also in *Iresine* (*I. spiculigera*, Seub.). Uniseriate clothing hairs having pointed ends and consisting of several short basal cells and one or more longer terminal cells, which are either smooth or papillose, occur also in species of *Gomphrena*. *Froelichia tomentosa*, Moq. has uniseriate clothing hairs composed of a basal

cell which is differentiated as a pedestal and is followed by two or three short and narrow cells, and a longer pointed terminal cell (Seubert).

Literature: Seubert, in Martius, Flora brasil., v, i, 1875, Tab. 50 et seq.—Viret, Liaisons du phloème méd. etc., Institut bot. de Genève, 1904, pp. 18–35 (*Achyranthes*).

CHENOPODIACEAE (pp. 655–663).

1. To the REVIEW OF THE ANATOMICAL FEATURES we may add that unicellular hairs occur in this Order, but are only very rarely found (*Salsola*).

2. The STRUCTURE OF THE LEAF has recently been examined especially by Montell[1], and further statements will also be found in Solms-Laubach's work (loc. cit.). The structure of the **mesophyll** in *Kirilowia eriantha*, Bunge (Tribe Camphorosmeae) conforms to the second of the special types mentioned in the earlier part of this work, while *Camphorosma monspeliacum*, L. belongs to the third type (Montell). According to Montell, however, ordinary types of leaf-structure are also found in the Order, e.g.: bifacial structure with one or more layers of palisade tissue on the upper and rather dense spongy tissue on the lower side (species of *Anthochlamys, Beta, Chenopodium, Spinacia*, &c.); a homogeneous mesophyll composed of rounded cells (*Axyris hybrida*, L.); centric structure with one or more vascular bundles occupying a central position and a sheath of one or more layers of palisade tissue beneath the epidermis (*Lophiocarpus polystachyus*, Turcz., *Kochia hirsuta*, Nolte) or centric structure with a mesophyll formed entirely by short palisade-cells (*Beta maritima*, L.).

The following details are taken from Solms-Laubach's investigations. In some of the species of *Suaeda* (*S. Forskalii*, Solms, *S. pruinosa*, Lge. and *S. vermiculata*, Forsk.) as well as in *Schanginia baccata*, Moq. and *S. hortensis*, Moq. the arc-shaped vascular system, which occupies a central position, is enveloped from within outwards by the following sequence of tissues: (*a*) first by aqueous tissue; then (*b*) by a sheath of collecting cells; and (*c*) finally by a single layer of palisade tissue situated beneath the epidermis. In other species of *Suaeda* (*S. altissima*, Pall., *S. fruticosa*, L., *S. maritima*, L., *S. physophora*, Pall., *S. salsa*, Pall., *S. setigera*, DC.), on the other hand, there is nothing but palisade tissue (comprising several layers of cells in the radial direction) between the epidermis and the vascular network. The same structure of the leaf, as is figured in Fig. 158, *B* (p. 656) after Volkens for a plant described as *Salsola longifolia*, Forsk., but considered by Solms to belong to *S. Sieberi*, Presl, is found according to the latter authority also in *Salsola oppositifolia*, Desf., *S. Schweinfurthii*, Solms, *S. tetragona*, Delile, *S. vermiculata*, L., *Halogeton alopecuroides*, Moq., *Traganum nudatum*, Delile and *Sevada Schimperi*, Moq.; these species likewise show vascular strands which branch off from the median vascular bundle and run in the aqueous tissue.

Special sheaths like those previously described are developed in the **veins** of the leaf also in species of *Corispermum* (Corispermeae). Sclerenchyma is found accompanying the median vein in *Ceratocarpus arenarius*, L. and *Grayia polygaloides*, Hook. et Arn. (Montell).

The transverse arrangement of the **stomata** mentioned on p. 658 has been observed also on the stem of *Camphorosma monspeliacum* (Cassan).

To the section dealing with the **hairy covering** we may in the first place add that short unicellular clothing hairs, appearing to the naked eye as small bristles, actually occur in *Salsola* (*S. Tragus*, L.), so that contrary to the earlier

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[1] Montell's investigations deal with the following genera: *Rhagodia, Lophiocarpus, Chenopodium* incl. *Blitum, Roubieva, Beta, Oreobliton*; *Spinacia, Atriplex, Grayia, Ceratocarpus*; *Axyris, Camphorosma, Kirilowia*; *Corispermum, Anthochlamys*; *Polycnemum*; *Chenolea* incl. *Echinopsilon, Kochia, Enchylaena*; *Suaeda*; *Salsola, Anabasis, Nanophytum, Sympegma*.

statement unicellular trichomes[1] are not wanting in all the Chenopodiaceae. Among the members of the Camphorosmeae, in which Montell records clothing hairs with a long terminal cell bearing papillae, ***Enchylaena tomentosa***, R. Br. deserves special mention, owing to the great length of the papillae in this species.

Vesicular hairs in which the terminal cell shows varied differentiation (sometimes even in one and the same species) were observed by Montell also in species of *Roubieva*, *Oreobliton*, *Spinacia* and *Chenolea* (*Echinopsilon*). In some of the vesicular hairs found in *Chenopodium anthelminticum*, L. and *Roubieva multifida*, Moq. the terminal cell is two-armed.

True glandular hairs, which secrete oil and have a structure similar to that figured in Fig. 150, *O*, are found in *Roubieva multifida*, which I have myself examined.

In certain members of the Order the clustered crystals of **oxalate of lime** fill large idioblasts in the mesophyll. Cells containing crystal-sand were observed by Montell in the mesophyll in the following additional cases: *Beta* pro parte, *Corispermum* (pro parte, side by side with clustered crystals), *Enchylaena tomentosa*, R. Br., *Nanophytum juniperinum*, C. A. Mey., *Oreobliton thesioides*, Dur. et Moq. and *Suaeda altissima*, Pall. (whilst other species of *Suaeda* have no oxalate of lime in the leaf). A subepidermal layer containing clustered crystals occurs also in the leaf of *Salsola Soda*, L. (but not in that of *S. Kali*, L.).

3. Structure of the Axis. The development of the **cork**, which is described as pericyclic on p. 662, has been carefully studied by Leisering. It is a familiar fact that the cork in this case occasionally arises so near to the anomalous vascular system that it appears to take its origin in the meristem, which produces the anomalous secondary growth of the latter. It has now been shown that the cells of the cork-cambium either belong to the parenchymatous pericycle or are given off on its outer side by the meristem just referred to. In *Atriplex hastata*, L. the place of origin of the cork varies in one and the same transverse section; at certain points the cork is found immediately external to the groups of pericyclic sclerenchyma, while at other points it is situated immediately on their inner side. According to Leisering the cork in *Eurotia ceratoides*, C. A. Mey. includes lamellae composed of one or two layers of uniformly sclerosed cells. In the species just named, as well as in *Haloxylon Ammodendron*, Bge. and *H. articulatum*, Bge., Jönsson records a peculiar process of gelatinization among the cells of the cork. In these species the cork besides containing cells of the normal type includes 'phelloid-cells' (occasionally containing small crystals of oxalate of lime), which ultimately come to have a spherical shape and become separated from one another as a result of the gelatinization of their middle lamellae and of the inner layers of their membranes.

As regards the occurrence of tracheids with a spiral strengthening band (see p. 663), we may add that in *Salicornia herbacea* Montell records a small number of imperfectly differentiated tracheids, while in *S. macrostachya* he figures spiral tracheids side by side with spicular cells.

The following additional details regarding the **anomalous structure of the fibrovascular system of the root** (see p. 663) are taken from Fron's investigations. The arrangement of the bundles of wood and bast is the same

[1] Montell (loc. cit., p. 20) correctly records unicellular trichomes in *Salsola*; on the other hand his statement to the effect that such hairs occur in *Kochia scoparia*, Schrad. is incorrect, as I have found by an investigation of this species. The capitate hairs, which Montell (loc. cit., pp. 39, 49 and 70, 71) figures as unicellular in species of *Chenopodium*, *Oreobliton* and *Atriplex*, no doubt in all cases have a distinct uni- or multicellular stalk; reinvestigation of *Atriplex portulacoides*, L., at all events, showed this to be the case in this species.

as in the stem. Concentric rings of bundles (Type I) are found in species of *Beta, Camphorosma, Chenopodium, Corispermum, Kochia,* and *Spinacia,* being incomparably more abundant than in the stem; but the second type, in which the vascular bundles are embedded in prosenchymatous conjunctive tissue, has also been observed, the bundles not uncommonly exhibiting a spiral arrangement. Fron has shown that this spiral arrangement takes its origin in an irregular differentiation of the primary (diarch) vascular system, and becomes intensified in the first place during the course of the normal growth in thickness and subsequently during the anomalous growth; the spiral arrangement may, moreover, be explained as a result of the position of the radicle in the seed and of the mechanical pressure, which is exerted upon it by the cotyledons. This spiral arrangement has been found both in the main root, developed from the radicle, and in the lateral roots; it is only a specific character, being recorded by Fron in species of *Anabasis, Atriplex, Chenopodium, Haloxylon, Obione, Salicornia, Salsola* and *Suaeda*. It remains to mention that in one and the same species the vascular bundles of the root are occasionally arranged according to the first type, while those of the stem are arranged according to the second type: this is the case in *Beta, Blitum, Spinacia,* and a few species of *Chenopodium* (e.g. *C. Bonus Henricus, C. murale* and *C. rubrum*).

Literature: [Paschkis, Pharmakogn. Beitr., Zeitschr. österreich. Apotheker-Ver., 1880, n. 27, 28; abstr. in Bot. Centralbl., 1881, i, p. 54 (*Chenopodium*).]—Mangin, Cellules spiralées, Bull. Soc. bot. de France, 1882, p. 16; and Ann. sc. nat., sér. 6, t. xiii, 1882, pp. 214, 215.—Schulz, Epidermiszellen bei *Salicornia herbacea*, Ber. deutsch. bot. Gesellsch. 1886, p. 52.—[Vibouchevitch, Plantes des terrains salants, Rev. sc. nat. appliquées, 1893; cited from Montell.]—[Pammel, Russian Thistle (*Salsola Kali*), Bull. Iowa Agricult. College Exp. Stat., n. 26, 1894, 33 pp.]—[Pontebnia, Ét. sur les halophytes de la Crimée, 1894; cited from Montell.]—[Tognini, Stomi, Atti Ist. bot. Pavia, 1894.]—Fron, Racine des *Suaeda* et des *Salsola*, Comptes rendus Paris, cxxv, 1897, pp. 366–8.—Fron, Struct. spiralée des rac. d. cert. Chenopodiac., Comptes rendus Paris, cxxvii, 1898, pp. 563–5; and Betterave, loc. cit., pp. 397–400.—Fron, Rech. anat. sur la racine et les tiges des Chenopodiac., Ann. sc. nat., sér. 8, t. ix, 1899, pp. 157–240 and Pl. v–x.—Herzog, Monogr. d. Zuckerrübe, Hamburg, 1899, p. 4 et seq.—Hirsch, Entwickl. d. Haare, Diss., Berlin, 1899, p. 29.—Leisering, Korkbild. bei den Chenopodiac., Ber. deutsch. bot. Gesellsch., 1899, pp. 243–55 and Tab. xix.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 9–11.—Cassan, *Camphorosma monspeliaca*, Thèse, Montpellier, 1901, pp. 31–46.—Solms-Laubach, Spirolobe Chenopodeen, Bot. Zeit., 1901, i, pp. 168–70.—Jönsson, Wüstenpfl., in Lunds Univers. Årsskrift, xxxviii, Afd. 2, n. 6, 1902, pp. 6–18 and Tab. i, ii (*Haloxylon, Eurotia*).—Pons, *Atriplex*, Nuovo Giorn. bot. Ital., N. S., ix, 1902, pp. 35–48 and Tab. i.—Theorin, Växttrichom., Arkiv för Bot., i, 1903, p. 173.—Chrysler, Strand-plants, Bot. Gazette, xxxvii, 1904, p. 461 et seq. (*Atriplex*).—Sarton, Anatomie d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 53–9 (*Atriplex*).—Holtermann, Einfluss d. Klimas, 1907, pp. 81, 85 and 86 (*Atriplex, Arthrocnemum, Salicornia, Suaeda*).—Montell, Anat. comp. de la feuille des Chenopodiac., Thèse, Paris, 1906; also in Perrot, Travaux, iv, 1907, 156 pp.

BASELLACEAE (pp. 663, 664).

Large spherical mucilage-cells are found in the mesophyll also in *Basella paniculata*, Volkens.

Literature: Volkens, *Basella paniculata*, in Engler, Bot. Jahrb., xxxviii, 1905, p. 81.

PHYTOLACCACEAE (pp. 664–668).

1. Review of the Anatomical Features. We may first add that anomalous structure of the root has been recorded also in *Agdestis, Petiveria* and *Rivina*, and anomalous structure of the stem also in *Agdestis* and *Barbeuia*. The earlier statement to the effect that clustered crystals of oxalate of lime are absent requires modification since they have been observed in *Stegnosperma* by Walter. According to the same authority sphaerites occur in *Barbeuia*.

2. Structure of the Leaf. Walter has recently undertaken a careful

investigation of the stomatal apparatus in this Order and finds that the Rubiaceous type is not sufficiently widely distributed in any genus to admit of its being regarded as a true generic character. He observed that the **stomata** are in all cases provided only with a number of ordinary neighbouring cells in the genera *Achatocarpus, Agdestis, Anisomeria, Barbeuia, Didymotheca, Ercilla, Gyrostemon, Microtea, Phaulothamnus, Seguieria, Stegnosperma* and *Tersonia*.

The same author makes the following statements (some of them new) regarding the mode of excretion of **oxalate of lime**. The genera *Phytolacca, Anisomeria* and *Ercilla* (Phytolacceae) possess raphides, while *Barbeuia* belonging to the same taxonomic group has sphaerites. The typical members of the Rivineae (*Gallesia, Ledenbergia, Mohlana, Monococcus, Petiveria, Rivina, Schindleria, Seguieria, Villamilla*) are distinguished by having styloids, whilst the genus *Stegnosperma*, which forms the group Stegnospermoideae in Walter's system of classification, is characterized by the possession of clustered crystals (sphaerites according to Schulze, see Syst. Anat., p. 665). The typical members of the Gyrostemoneae (*Codonocarpus, Didymotheca, Gyrostemon, Tersonia*) have no oxalate of lime at all. Regarding the remaining genera, which are excluded from the Phytolaccaceae by Walter, we may mention the following details on his authority. *Agdestis* (' Genus anomalum Phytolaccac.' in Bentham and Hooker, Gen. Plant.), and *Gisekia* (a member of the Ficoideae in Bentham and Hooker, Gen. Plant.) are provided with raphides; *Limeum* and *Semonvillea* (members of the Ficoideae in Bentham and Hooker, Gen. Plant.) have clustered crystals, while *Microtea* has sphaerites. In *Phaulothamnus* Walter observed only small crystals of oxalate of lime (in the ovary), while in *Achatocarpus, Adenogramma* and *Polpoda* he failed to find any oxalate of lime at all.

3. Structure of the Axis. Regarding the recently discovered cases of **anomalous structure** in the fibrovascular system of the stem and root, see above under 1, and Walter, loc. cit.; for *Agdestis*, see also Cobau, loc. cit. In the stem and root of *Agdestis clematidea*, Moç. et Sessé the secondary zones of vascular bundles develop in the pericycle (Cobau). Walter failed to observe anomalous growth in thickness in the axis of the following genera: *Achatocarpus, Adenogramma, Codonocarpus, Didymotheca, Gisekia, Gyrostemon, Ledenbergia, Limeum, Microtea* (here also wanting in the root), *Monococcus, Persoria, Phaulothamnus, Polpoda, Psammotropha, Rivina, Semonvillea, Stegnosperma, Tersonia* and *Villamilla*.

The perforations of the **vessels** are invariably simple also in the genera *Achatocarpus, Adenogramma, Agdestis, Barbeuia, Didymotheca, Gisekia, Ledenbergia, Limeum, Mohlana, Monococcus, Petiveria, Phaulothamnus, Polpoda, Psammotropha, Schindleria, Semonvillea, Stegnosperma, Tersonia* and *Villamilla*. In *Adenogramma, Agdestis, Anisomeria, Barbeuia, Didymotheca, Ercilla, Gisekia, Limeum, Microtea, Monococcus, Petiveria, Phaulothamnus, Polpoda, Psammotropha, Semonvillea, Stegnosperma* and *Tersonia* the walls of the vessels, where in contact with parenchyma, are occupied by bordered pits; in *Achatocarpus* and *Villamilla* there are both bordered and simple pits at these points, and in *Ledenbergia, Mohlana* and *Rivina* simple pits only.

Literature: Cobau, Anatomia della *Agdestis clematidea*, Boll. R. Orto bot. di Palermo, ii, 1898, pp. 111–22.—[Kraemer, The pith-cells of *Phytolacca decandra*, Torreya, ii, 1902, pp. 141–3.] —Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 167.—Netolitzky, Dikotylenbl. (Rhaphiden), 1905, p. 38.—Walter, Diagramme der Phytolacc., Diss., Erlangen, 1906, pp. 58–61; also in Engler, Bot. Jahrb., xxxvii.—[Senft, Radix Phytolaccae decandrae, Pharm. Post, 1906, p. 281.]—[Holm, *Phytolacca decandra*, in Merck's Report. xvi, 1907, pp. 312–14.]

BATIDEAE (pp. 668, 669).

According to Van Tieghem a particularly noteworthy feature lies in the arrangement and course of the **vascular bundles** in the quadrangular stems, which bear opposite leaves. Corresponding to each of the angles of the stem there are 3–5 bundles in the vascular ring, these bundles being separated from one another by multiseriate medullary rays, while opposite each lateral surface of the stem there is a single smaller vascular bundle. The two smaller bundles belonging to two opposite sides of the stem show a decrease in size as they are traced up towards the next node above; they first loose their xylem, and after that their phloem, while ultimately—in the neighbourhood of the node—even the strand of pericyclic bast-fibres belonging to the bundle disappears. These smaller vascular bundles therefore do not pass out into the petiole, which is supplied by the two nearest of the bundles corresponding to the angles of the stem. These bundles fork and the two middle bundles thus produced fuse to form a single median bundle, the lateral branches thereupon forking once again. In this way the base of the leaf is supplied by five vascular bundles, which are arranged in an arc.

Van Tieghem records clustered crystals of **oxalate of lime** in the pith and primary cortex, and solitary and clustered crystals in the medullary rays of the bast. The peculiar transverse arrangement of the pairs of guard-cells is found also on the axis.

Literature: Van Tieghem, Batidacées, Journal de Bot., 1903, pp. 363–76, especially pp. 365–7.

POLYGONACEAE (pp. 669–674).

1. Review of the Anatomical Features. We may add that secretory cavities containing a resinous secretion occur in species of *Polygonum*, and that simple uniseriate clothing hairs and shaggy hairs have been observed in this Order. Cortical vascular bundles, situated in the pericycle, are found also in *Rumex biformis*.

2. Structure of the Leaf. The upper **epidermis** of the leaf contains numerous cells with gelatinized inner membranes also in *Polygonum acre*, H. B. K.; these cells are almost spherical and penetrate rather deeply into the mesophyll, while their lumina in most cases include a body, which resembles a clustered crystal and refracts the light doubly; this body is soluble in hydrochloric and sulphuric acids, as well as in caustic potash (in the latter case a simply refracting skeleton remains undissolved). The **stomata** in *Polygonum acre* occur in small numbers on the upper side of the leaf as well, and are provided with subsidiary cells arranged according to the Rubiaceous type. Perdrigeat describes three neighbouring cells as of quite general occurrence.

Unicellular clothing **hairs** are found in *Antigonon* (Perdrigeat). The long conical shaggy hairs present on the margin and median vein of the leaf in *Polygonum acre* are composed of lignified fibrous cells with thick walls and narrow lumina. The same species also has discoid glands with a low bicellular stalk and a multicellular head, divided by vertical walls.

To the section dealing with the internal **secretory receptacles** we may add that Peltrisot has observed secretory cavities, which are of quite a peculiar type and have oily-resinous contents, in the leaves and branches of *Polygonum Hydropiper*, L. These cavities are schizogenous in origin and are surrounded by four epidermal cells, which penetrate into the primary cortex or mesophyll as the case may be. To judge by analogy the 'secretory cells (or secretory cavities),' previously recorded in two other species of *Polygonum* (*P. acre* and

P. punctulatum) are probably also of the nature of cavities in all cases. This is at least true of *P. acre*, as I have found by an investigation of this species. In this plant the secretory cavities are likewise situated in direct contact with the two surfaces of the leaf, but they are surrounded by a relatively large number of low epithelial cells; it remains to be investigated whether all these epithelial cells and consequently the secretory cavities themselves are of epidermal origin in this case. Tannin appears to be very widely distributed in the Polygonaceae, especially among the desert-plants.

The clustered crystals of **oxalate of lime** present in the primary cortex and mesophyll occasionally attain quite a considerable size (e.g. in *Polygonum acre*).

For the structure of the **petiole** (the vascular bundles of which are invariably isolated) and of the stipular ochrea, see also Perdrigeat, loc. cit.

3. Structure of the Axis. Numerous new statements on the structure of the stem will be found in Perdrigeat's paper, which deals with species of all the genera enumerated in Durand's Index with the exception of *Hollisteria*. This piece of work is mainly concerned with the vascular system of the axis and leaf and with the structure of the cortex, while the treatment of the hairy covering and the secretory organs is inadequate.

The following details regarding the structure of the **cortex** are taken from Perdrigeat's paper and the remaining literature. Assimilatory tissue in the form of palisade-parenchyma is found in the primary cortex not only in *Calligonum comosum* (see Fig. 162 on p. 673), but also in species of *Chorizanthe* and *Oxytheca*. In an undetermined species of *Calligonum* examined by Jönsson the outer parts of the walls of the epidermal and hypodermal cells become swollen, so that the cell-cavities, which are surrounded by the inner parts of the walls, appear as though they were embedded in a mass of mucilage. The endodermis may be provided with Caspary's dots on its radial walls (e.g. in *Koenigia islandica*, L.); in *Rumex Patientia*, L. it is sclerosed. According to Perdrigeat the **pericycle** is invariably sclerenchymatous in the subaerial parts of the stem; it contains either isolated bundles of fibres or a closed or slightly interrupted ring of fibres or a composite and continuous ring of sclerenchyma; the latter has been recorded in *Campderia floribunda, Coccoloba, Eriogonum sphaerocephalum*, Dougl., *Leptogonum domingense*, Benth., and *Podopterus mexicanus*, Humb. et Bonpl. The bundles of pericyclic fibres show a radial development similar to that found in *Calligonum comosum* (see Fig. 162) also in species of *Coccoloba* and *Pterococcus*. The **cork** arises subepidermally also in *Coccoloba, Rumex tingitanus*, and *Triplaris americana*, 'superficially' (probably in part in a subepidermal position) in *Calligonum comosum*, L'Hérit., *Eriogonum 'panifolium,' Leptogonum domingense*, Benth., *Podopterus mexicanus*, Humb. et Bonpl., *Pterococcus, Ruprechtia apetala* and *Symmeria paniculata*, while it develops in the pericycle also in *Harfordia macroptera*, Greene et Parry and *Pteropyrum scoparium*, Jaub. et Spach. The cells of the cork for the most part have thin walls. In *Ruprechtia apetala* there is an alternation of layers of cork-cells with thick and thin walls; in *Harfordia macroptera* the cells of the cork have strongly thickened tangential walls, while in *Coccoloba Schomburgkii* they are thickened in the shape of a horseshoe. In the species examined by Jönsson (*Calligonum* sp., *Atraphaxis canescens*, Bge. and *A. spinosa*, 'Eichw.') the cork contains 'mucilaginous cork-cells' (see under Chenopodiaceae, p. 1029). The secondary bast not uncommonly includes chambered parenchyma with clustered crystals, but bast-fibres are rare (*Rumex scutatus*, L.).

In many members of the Order and especially in the herbaceous forms there is a lysigenous cavity in the **pith**, whilst in *Nemacaulis Nuttallii*, Benth., for example, the entire pith becomes lignified at an early stage and is therefore

persistent. The occurrence of bundles of fibres, which are often very strongly developed, or of a zone of fibres at the margin of the pith is a very common feature (e.g. in species of *Campderia, Coccoloba, Emex, Oxyria, Podopterus, Pteropyrum, Rumex, Triplaris,* &c.).

Anomalous structure of the stem has recently been demonstrated also in *Rumex biformis* (in the form of variously orientated vascular bundles, which are enclosed in the pericyclic strengthening ring), as well as in *Rumex conglomeratus,* Murr., *R. intermedius, R. obtusifolius, R. purpureus,* Poir., *Rheum hybridum,* Murr., *R. leucorrhizum,* Pall. and *R. undulatum,* L. (medullary vascular bundles, the records in the species of *Rheum* referring to the axis of the inflorescence) (Baranetzky, Perdrigeat, Saget).

Literature: [Theorin, Växtslem uti knopparne hos fam. Polygon., Stockholm, 1872.]—Schubert, Parenchymscheiden, Bot. Centralbl., 1897, iv, pp. 469–71.—Wollenweber, Anat. d. Schwimmbl., Diss., Freiburg in Br., 1897, pp. 33, 34.—Hämmerle, *Polygonum cuspidatum,* S. et Z., Diss., Göttingen, 1898, 70 pp.—Montemartini, Fusto del *Polygonum Sieboldii,* Reinw., Malpighia, 1898, pp. 78–80 and Tab. iii.—Boergesen og Paulsen, in Bot. Tidsskrift, xxii, 1898–9, pp. 16–18 (*Coccoloba uvifera,* Jacq.).—Baranetzky, Faisceaux bicollatéraux, Ann. sc. nat., sér. 8, t. xii, 1900, pp. 307–14.—[Bernatsky, Anat. Bestimm. einheim. *Polygonum*-Arten, Termesz. Füzetek, xxiii, 1900, pp. i, ii and pp. 66–74.]—Thomas, Feuilles sout., Thèse, Paris, 1900.—Dye, Unterird. Org. von *Valeriana, Rheum* u. *Inula,* Diss., Bern, 1901, pp. 36–64 and Tab. i, ii.—Perdrigeat, Anat. comp. des Polygonac., Act. Soc. Linn. de Bordeaux, lv, 1901, 94 pp., 3 pl.; also Thèse, Bordeaux.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 48.—Jönsson, Wüstenpfl., in Lunds Univ. Årsskr., xxxviii, Afd. 2, n. 6, 1902, pp. 18–22 and Tab. ii (*Calligonum, Atraphaxis*).—[Mitlacher, Herba *Polygoni avicularis,* Pharm. Post, 1902, n. 56; abstr. in Just, 1902, ii, p. 45.]—Peltrisot, Org. sécrét. du *Polygonum Hydropiper,* L., Journ. de Bot., 1903, pp. 223–8.—Saget, Ét. anat. des *Rumex crispus* et *R. obtusifolius,* etc., Thèse, Montpellier, 1903, pp. 26–31.—Chrysler, Strand-plants, Bot. Gazette, xxxvii, 1904, p. 461 et seq. (*Polygonum*).—Eijken, Rhabarberrhizome, Diss., Bern, 1904, p. 45 et seq.—Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, pp. 37, 38.—Cristofoletti, *Rheum raponticum,* Diss., Bern, 1905.—Porsch, Spaltöffnungsapparat, Jena, 1905, p. 87 and Tab. ii.—[Litschauer, Eingesenkte epid. Drüsen bei *Polygonum Hydropiper,* Österreich. bot. Zeitschr., 1907, pp. 201–4.]—[For further literature, see p. 1171.]

PODOSTEMACEAE (pp. 674–676).

The following details are taken from recent papers on the anatomy of the Podostemaceae. According to Mildbraed the drifting stems are constructed so as to have tensile strength. In the **axis** of *Mourera fluviatilis,* Aubl. this author observed a central cylinder, which consists of long pitted mechanical cells and is traversed by air-canals, while the peripheral tissue contains a large number of isolated vascular bundles which are arranged in three indistinct rings and show the ordinary type of structure; in the neighbourhood of the air-canals of the central cylinder, moreover, spiral and annular vessels were found. The stems of the Apinagieae examined by Mildbraed (especially *Apinagia Riedelii,* Tul.) have a central vascular bundle, which includes an air-canal and is enveloped by a rather thick stereom-cylinder composed of lignified cells bearing slit-shaped pits. These statements serve to show that mechanical cells are not as rare in this Order as has hitherto been supposed.

H. Möller observed cubical and prismatic crystals of **oxalate of lime** in the epidermis of the root of *Cladopus Nymani,* Möll.; previous to that only clustered crystals had been recorded in the Podostemaceae. In the event of fresh investigations being undertaken on the members of this Order it will be well to devote special attention to the occurrence of intercellular **secretory receptacles.** Secretory spaces resembling resin-canals had previously been observed by Wächter in the root of *Weddellina squamulosa,* and on Mildbraed's authority we may class with them the following two types of elements: (*a*) Secretory cavities, which have yellow resinous contents soluble in alcohol and are apparently lysigenous in origin, in the outer tissues and central cylinder of the scape of *Mourera fluviatilis*; (*b*) the secretory cavities, which occur in the

thallus of *Castelnavia Lindmaniana*, Warm., and appear in the form of brownish streaks in alcohol-material; they arise lysigenously from a row of about 3–10 secretory cells; their secretion is in part thread-like and granular and undergoes but little change on treatment with alcohol, ether or xylol. Here we may call to mind the fact that Goebel likewise observed the exudation of a yellow secretion on cutting fresh stems of *Rhyncholacis macrocarpa*, Tul.; the organs in which the secretion is contained have not yet been demonstrated in this case.

It remains to consider the '**red bodies**' ('Warming's bodies'), which have been subjected to a careful examination by Mildbraed. They were first observed by Warming in the spathella of *Apinagia Riedelii*, but occur also in the wall of the capsule and in the thallus of *Castelnavia Lindmaniana*. Judging by the reactions mentioned by Mildbraed it seems as though we were after all dealing with silica-bodies, which are infiltrated with a substance resembling anthocyanin, although Mildbraed's statement that these bodies are not affected by hydrofluoric acid is incomprehensible in this connexion. In view of the other reactions, however, of what can the ground-substance consist, if not of silica?

Literature: Hjalmar Moller, *Cladopus Nymani*, nov. gen., Ann. Jardin Buitenzorg, xvi, 1899, pp. 115–31 and Tab. xii–xv.—Warming, Fam. Podostemac., Afh. v, 1899; and Afh. vi, 1901, Vidensk. Selsk. Skr.—[Willis, Podostemaceae of Ceylon and India, Ann. Roy. Bot. Gardens, Peradeniya, i, Part iv, 1902, pp. 267–465 and pl. iv–xxxviii; detailed abstract in Bot. Centralbl., xcii, pp. 193–8.]—Mildbraed, Beitr. z. Kenntnis der Podostemac., Diss., Berlin, 1904, 42 pp.

NEPENTHACEAE (pp. 676–680).

According to Fenner's investigations the **digestive glands** (p. 677) of *Nepenthes Rafflesiana*, Jack are of the nature of emergences, since subepidermal cells are also concerned in their formation. The same author also states that the cuticle of the glands is perforated in a sieve-like manner, and that the walls of the cells composing the uppermost layer of the body of the gland are provided with membranous ridges. In *Nepenthes Rafflesiana* the outer wall of the pitcher bears various types of hairs including peculiar clothing hairs with dendroid branching.

With reference to the structure of the **axis** (p. 679) we may note that, according to Heinricher, the vessels in *Nepenthes melamphora*, Reinw. attain a diameter of ·18 mm., that spiral tracheids are found also in the medullary rays of the cortex, and that fusiform proteid-bodies occur abundantly in the cortical parenchyma of the rhizome, but only in small numbers in the cortex of the climbing stem.

Literature: Mangin, Cellules spiralées, Bull. Soc. bot. de France, 1882, p. 14 et seq., and Ann. sc. nat., sér. 6, t. xii, 1882, pp. 212–14 and pl. viii.—Fenner, Anat., Entwicklungsgesch. u. Biologie der Laubbl. u. Drüsen einiger Insektivoren, Diss., Zürich, 1904, pp. 28–33 and Tab. ix, x; also in Flora, xciv, 1904.—Heinricher, *Nepenthes*, Ann. Jardin bot. Buitenzorg, xx, 2, 1906, pp. 277–98, and Tab. xxiv–xxvi.

CYTINACEAE (pp. 680, 681).

Tracheids have been observed in the myceloid vegetative thallus of *Pilostyles Ingae* (Karst.), by Endriss, while on the lower side of the scale-leaves borne on the floral shoots of this plant the same author found stomata, which are formed by a single division in the epidermal cells. Stomata have recently been observed also by Porsch on the under side of the lowest scale-leaves in *Cytinus Hypocistis*, L. Schaar's investigation of *Rafflesia Rochussenii*, Teysm. et Binn. has shown that the vegetative thallus in this species consists only of hyphal

cells and that the conducting tissue, which is differentiated in the floral cushion, is formed by about 20 rings of vascular bundles exhibiting an annular arrangement.

Literature: Schaar, *Rafflesia Rochussenii*, Sitz.-Ber. Wiener Akad., cvii, Abt. i, 1898, pp. 1039–56 and Tab. i–iii.—Solms-Laubach, Rafflesiaceae u. Hydnoraceae, in Pflanzenreich, Heft 5, 1901, Raffles. pp. 2, 3; Hydnor. p. 2.—Endriss, *Pilostyles Ingae*, Flora, xci, 1902, Ergänz.-Bd., pp. 209–36 and Tab. xx.—Porsch, Spaltöffnungsapparat, Jena, 1905, pp. 70–2.

ARISTOLOCHIACEAE (pp. 682–688).

2. Structure of the Leaf. A few data regarding the course of development of the stomata will be found in Montemartini's paper (loc. cit.). Papillae are present on the lower side of the leaf also in *Aristolochia elegans*, Mast. (Knothe). The following details regarding the structure of the **secretory cells** are based on investigations undertaken by Berthold, Haberlandt and R. Müller on *Asarum europaeum*, *Aristolochia brasiliensis* and *A. Clematitis*. In the fully differentiated oil-cell the drop of oil is completely enveloped by a sheath, the upper part of which is formed by the wall of a 'basin-' or funnel-shaped structure, which arises as a thickening from the cell-membrane, while the remaining portion of the sheath is constituted by the wall of the vacuole ('pouch'), which has undergone a change in substance. In a surface-section the 'basin' appears in the form of the pit-like structure represented in Fig. 166, *B* (on p. 684). R. Müller has also shown that the secretory cells in the leaf of *Aristolochia brasiliensis*, although apparently belonging to the integumental tissue, are differentiated in a subepidermal position, but they soon come to lie at the surface as the result of sliding growth. Since the statements hitherto published as to the occurrence of secretory cells in the epidermis are based only on an examination of the mature leaves, it will be necessary to undertake a developmental investigation in all these cases. According to Van Tieghem the absence of oxalate of lime in the branch and root and the possession of oil-cells are features characteristic of a certain group of species of *Aristolochia*, which he comprises as *Aristolochia*, L. in contrast to a second group of species (*Hocquartia*, Dumort.), which are distinguished by having clustered crystals and by the absence of oil-cells (also in the hairs).

3. Structure of the Axis[1]. According to Schellenberg the **pith** of *Aristolochia Sipho* and other twining species is composed of cells with thin unlignified walls, and undergoes compression so that the stem becomes adapted to resist tensions. Stone-cells occasionally also occur in the pith (*Aristolochia Sipho* and *A. gigantea*).

Literature: Power, *Asarum canadense*, Diss., Strassburg, 1880, pp. 9–11.—[Lazarski, *Asarum*, Pharm. Post, 1881, n. 3, 4; abstr. in Bot. Centralbl., 1881, ii, p. 49.]—Berthold, Protoplasmamechanik, Leipzig, 1886, p. 26.—[Hooper, *Bragantia Wallichii*, Americ. Journ. of Pharm., 1894, p. 231.]—Schwabach, Mech. Ring, Bot. Centralbl., 1898, pp. 354–7.—Schellenberg, Entwicklungsgesch. d. Stammes von *Aristolochia Sipho*, Festschr. f. Schwendener, 1899, pp. 301–20 and Tab. xii.—[Collin, *Aristolochia Serpentaria*, Journ. de Pharm. et de Chimie, 1900, p. 309; abstr. in Just, 1900, ii, p. 16.]—Van Tieghem, Hocquartie, Journ. de Bot., 1900, pp. 65–8.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 42–6.—Knothe, Unbenetzb. Epid., Diss., Heidelberg, 1902, p. 15.—Montemartini, Anat. comp. delle Aristoloch., Atti dell' Ist. bot. di Pavia, 2ᵃ ser., vii, 1902, pp. 229–50 and Tab. xii–xvi; sep. copy, pp. 5–10.—Perrot, Particularité de struct. fol. chez cert. feuilles de l'*Aristolochia Sipho*, Bull. Soc. bot. de France 1902, pp. 163–6.—Haberlandt, Physiol. Pflanzenanat., 3rd edit., 1904, pp. 462–4.—R. Müller, Ölbehälter, Ber. deutsch. bot. Gesellsch., 1905, pp. 292–7.—[Holm, *Aristolochia Serpentaria*, in Merck's Report, xvi, 1907, pp. 276–9.]

[1] Regarding the incorrect statement (in Perrot, Thèse, 1899, p. 144) as to the occurrence of secondary bundles of wood and bast in members of the Aristolochiaceae, see the footnote on p. 687.

PIPERACEAE (pp. 688–694).

2. STRUCTURE OF THE LEAF. In *Anemiopsis californica*, Hook. et Arn. the stomata are present on both sides of the leaf, being almost more abundant on the upper than on the lower side ; they are surrounded by 4–6 neighbouring cells. In the same species a **hypoderm** composed of a single layer of large cells is developed on the upper side of the leaf (Holm).

New data regarding the nature of the hypoderm in the Brazilian species of *Peperomia* are contained in Jaderholm's paper (loc. cit.). In the first place we may note that there is no hypoderm in *P. tenera*, Miq. and *P. pellucida*, H.B.K. ; in the latter species the large-celled epidermis which is differentiated as aqueous tissue compensates for the absence of hypoderm. In *Peperomia Gardneriana*, Miq. the hypoderm usually consists only of a single layer of cells ; in *P. diaphana*, Miq. it is composed of two layers, and in *P. Caldasiana*, C.DC. of several layers of cells, which in both cases are of large size ; in *P. trineuroides*, Dahlst. the hypoderm is developed in the same way as in *P. pereskiaefolia*. In *P. reflexa*, Dietr. it consists of very numerous layers, in *P. Sellowiana*, Miq. of several layers ; in the two species last named the inner hypodermal cells are arranged in rows at right angles to the surface of the leaf. Regarding the hypoderm found in the species of *Peperomia*, see also Jönsson, loc. cit.

According to Duval hypoderm (in some cases situated on both sides of the leaves) is found also in *Piper ceanothifolium*, H.B.K., *P. citrifolium*, Lam., *P. corcovadense*, C.DC., *P. Jaborandi*, Vell., *P. laetum*, C.DC., *P. mollicomum*, Kth., *P. reticulatum*, L., and *P. unguiculatum*, Ruiz et Pav. ; according to Holtermann also in *Piper Thwaitesii*.

In the Brazilian species of *Peperomia* examined by Jäderholm the **palisade tissue** consists of a single layer of short funnel-shaped cells. It is typically differentiated only in *P. muscosa*, Link (?), although even here the cells are of no great length. In the peculiar leaves of *P. dolabriformis*, H. B. K. and *P. nivalis*, Miq. palisade tissue is completely wanting : for details regarding the structure of these leaves, see C. de Candolle, loc. cit. According to Jäderholm *P. Caldasiana* and *P. Sellowiana* are distinguished by the fact that the cells of the uppermost layer of the spongy tissue, which borders on the palisade tissue, have very thick walls and store up starch, while *P. pellucida* is characterized by the walls of the entire spongy tissue being hyaline. Conical papillae occur on the upper epidermis also in *P. increscens*, Miq. ; in *P. diaphana*, Miq. some of the upper epidermal cells are papillose.

Noteworthy forms of clothing **hairs** are constituted by the small 2–5-celled trichomes of *Peperomia pulchella*, A. Dietr., and the small unicellular hairs of *P. resedaeflora*, Lind. et André. These hairs are seated on a large epidermal cell, which is either vesicular or projects in a convex manner and constitutes an ocellar apparatus ; in the second of the two species the efficacy of this organ for the perception of light is further increased by a cell of characteristic shape, which is apposed to the inner side of the protruding epidermal cell and is occasionally differentiated as an oil-cell ; this cell and the one above it are both derived from the same mother-cell (Haberlandt). In this connexion we may mention the numerous flat tubercles, which are found on the surface of the leaf in *Peperomia metallica*, and according to Haberlandt function as lenses for the concentration of light ; they are formed by a group of epidermal cells showing tangential divisions. In this case an oil-cell which is situated exactly beneath the centre of each group of cells functions as a second condensing lens. For the diverse forms of trichomes found in *Piper*, and especially the clothing hairs, see Plate IX in Duval's paper, loc. cit.

Jäderholm mentions the occurrence of crystals of **oxalate of lime** resembling raphides also in *Peperomia major*, C. DC., while Duval records them

in certain species of *Piper*. Brownish acicular crystals, which are soluble in acetic acid (and therefore do not consist of oxalate of lime), were observed by Jäderholm in the axis of *Peperomia trineuroides*, Dahlst.

Haberlandt has recently demonstrated the importance of the **secretory cells** in certain species of *Peperomia* as organs for the condensation of light. We may add that in this Order, as in the Aristolochiaceae, the oily secretion is enclosed in a pouch-shaped protrusion of the cell-wall, a feature which is very distinctly seen, for example, in *Peperomia magnoliaefolia* (Berthold and R. Müller). The nature of the secretory cavities (' poches sécrétrices '), recently observed by Duval side by side with the secretory cells in the mesophyll of *Piper hirsutum*, Sw., still requires further investigation. According to Duval mucilage-canals are found in the pith also in *Piper ceanothifolium*, H. B. K., *P. citrifolium*, Lam. and *P. lepturum*, Kth. (in the last of these species in addition to mucilage-cavities, which are situated in the soft bast of the vascular bundles).

3. Structure of the Axis. Among the species of *Piper*, examined by Duval, *P. Jaborandi*, Vell. alone has medullary **vascular bundles**. According to Jäderholm exceptions to the fourth type (the *Peperomia*-type) are constituted by *Peperomia delicatula*, Hench., which has four vascular bundles arranged in a ring, and by *P. tenera*, Miq., in which the vascular system consists of a single axile strand.

The terrestrial **roots** of *Piper nigrum* contain a pith ; in the course of their growth in thickness broad strips of thin-walled tissue constituting primary medullary rays are alone formed on the outer side of the (5–10) groups of primary tracheae. I failed to observe the small groups of thin-walled elements, which Keller records in the secondary wood and regards as being of the nature of interxylary phloem.

Literature: [Paschkis, Pharmakogn. Beitr., Zeitschr. österreich. Apotheker-Ver., 1880, n. 27, 28; abstr. in Bot. Centralbl., 1881, i, p. 54.]—Berthold, Protoplasmamechanik, Leipzig, 1886, p. 25.—Keller, Luftwurzeln, Diss., Heidelberg, 1889, pp. 30–3.—Went, Luftwurzeln, Ann. Jardin Buitenzorg, xii, 1895, pp. 47, 48.—Jönsson, Anat. Bau des Bl., Acta Univ. Lund., xxxii, 2, 1896 (*Peperomia*).—[True, Kava-Kava, Pharm. Review Milwaukee, xiv, 1896, pp. 28–32; abstr. in Just, 1896, ii, p. 479.]—Dethan et Bertaut, Nouv. variété de Matico, Journ. de Pharm. et de Chimie, sér. 6, t. vi, 1897, pp. 536–40.—Biermann, Ölzellen, Diss., Bern, 1898, pp. 50–3.—Jäderholm, Anat. studier öfver sydamerik. Peperomier, Diss., Upsala, 1898, 99 pp. and 2 Tab.; German abstr. in Bot. Centralbl., 1898, iv, pp. 190–3.—Siedler, Kawawurzel, Pharmazeut. Zeit., 1903, p. 781.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 168–70.—Haberlandt, Physiolog. Pflanzenanatomie, 1904, p. 462.—Haberlandt, Lichtsinnesorgane, 1905, pp. 114–17 and Tab. iii.—Holm, *Anemiopsis*, Americ. Journ. of Sc., xix, 1905, pp. 76–82.—R. Müller, Ölbehälter, Ber. deutsch. bot. Gesellsch., 1905, p. 297.—Duval, Jaborandis, 1905, pp. 95–110, and pl. ix; in Perrot, Travaux, iii, 1906.—C. de Candolle, Sur deux *Peperomia*, etc., Arch. sc. phys. et nat. Genève, 1907, sep. copy, 9 pp., 1 pl.—Holtermann, Einfluss des Klimas, 1907, p. 136.

CHLORANTHACEAE (pp. 695, 696).

According to H. Schulze's recent investigations the following additional characters are important for the **diagnosis of the Order**. The palisade tissue of the leaf consists of short cells and is often muriform. Arm-palisade cells have been observed in all the species, which have been investigated. The stomata are confined to the lower side of the leaf. Secretory cells have now been demonstrated also in *Ascarina*, and therefore occur in all the members of the Order.

To the earlier statements regarding the **secretory receptacles** we may add that H. Schulze likewise observed the secretory cells of the leaf only in the mesophyll. The relatively small secretory cells, which are particularly abundant in the mesophyll of *Hedyosmum racemosum*, Don, are exceptional in having dark brown contents. Mucilage-canals occur in the larger veins of the leaf also in *Hedyosmum arborescens*, Sw.

The **structure of the leaf** is in all cases bifacial. Typical **palisade tissue**

composed of long cells is not found in any member of the Order. All the species of *Chloranthus*, *Ascarina* and *Hedyosmum* have arm-palisade-cells, which vary in number in the different species and occur in the first and commonly also in the second and third layers of the palisade tissue. In *Hedyosmum arborescens* and *H. racemosum* the cells of the spongy tissue are slightly sclerosed at certain points. Schulze also states that distinct subsidiary cells are developed in relation to the **stomata** only in certain species. He records two or more subsidiary cells, which are placed parallel to the pore, for the stomata of *Chloranthus inconspicuus*, Sw. and *C. officinalis*, Bl., and subsidiary cells arranged in the form of a rosette round the stomata of *Ascarina polystachya*, Forst. The lateral walls of the **epidermal cells** are either straight or undulated. A continuous one-layered hypoderm beneath the upper epidermis, besides occurring in *Hedyosmum arborescens*, is found in *H. racemosum* and *Ascarina polystachya*, while the hypoderm is confined to the neighbourhood of the veins in *Chloranthus brachystachys*, Bl., *C. inconspicuus*, Sw., *C. japonicus*, Sieb., *C. officinalis*, Bl., *Hedyosmum Artocarpus*, Solms and *H. Bonplandianum*, H. B. K. In *Ascarina lanceolata*, Hook. f. and *A. polystachya*, Forst. the epidermal cells on the lower side of the leaf are characterized by their strikingly small size, while in *A. rubricaulis*, Solms they are distinguished by bearing characteristic papillae, which project in the form of crests in surface-view. According to Schulze the vascular bundles in the lateral **veins** of the first order are for the most part surrounded by slightly sclerosed parenchyma. In *Ascarina rubricaulis* this sclerenchymatous sheath is incomplete, while in *Chloranthus serratus*, Roem. et Schult. and *Hedyosmum nutans*, Sw. it is absent.

As regards the structure of the **wood** we may add that Engler records scalariform perforations (with numerous bars) in the vessels also in *Ascarina*.

The only form of crystals of **oxalate of lime** observed by Schulze were small solitary crystals in the upper epidermis of the leaf of *Chloranthus inconspicuus*, Sw.

APPENDIX: THE ANOMALOUS GENUS *Circaeaster*.

The genus *Circaeaster*, which in Durand's Index is appended to the Chloranthaceae as a 'genus anomalum,' differs quite essentially from the Chloranthaceae in the absence of secretory cells. There are no special anatomical features to give a hint as to the systematic position of the genus.

H. Schulze mentions the following details regarding the structure of the **leaves**, which are very thin. The upper epidermal cells are elongated in a direction parallel to the midrib of the leaf and have strongly undulated lateral walls. The stomata, which are found only on the lower side of the leaf, are small and not numerous; they have no subsidiary cells. There is no sclerenchyma in the veins. Both crystals and secretory cells are absent. Unicellular hairs, which are bent in the form of a hook at the apex, are present only on the fruit.

With reference to the structure of the **stem**, Scott (in Oliver's description of the genus, loc. cit.) states that the fibrovascular system is peculiar in being diarch like that of the main root; only a small amount of secondary wood and phloem is produced on the two sides of the diarch xylem-plate.

Literature: Oliver, in Hooker, Icones, pl. 2366, 1895.—Harms, in Nachtr. zu den natürl. Pflanzenfam., ii–iv, 1897, p. 333.—H. Schulze, in Beih. z. Bot. Centralbl., ix, 1900, pp. 81–5.

MYRISTICACEAE (pp. 696–699).

Literature: Poulsen, Abnorme rodbygning hos en art af sl. *Myristica*, Vidensk. Meddelels., 1896, p. 188 and Tab. iii, iv.—Biermann, Ölzellen, Diss., Bern, 1898, p. 47.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 93.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 296.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 35, 36.

MONIMIACEAE (pp. 699–702).

2. STRUCTURE OF THE LEAF. The following details are taken from Perkins' recent anatomical investigations[1], which serve to supplement Hobein's earlier work. In the large majority of cases the structure of the leaf is bifacial. In *Amborella trichopoda*, Baill. typical palisade tissue is wanting, while in *Trimenia weinmanniifolia*, Seem., *Piptocalyx Moorei*, Oliv. and *Glossocalyx Staudtii*, Engl. the entire mesophyll is composed of spongy tissue. **Hypoderm** has been recorded also in *Anthobembix*, *Ephippiandra*, *Levieria*, *Macropeplus*, *Macrotorus*, *Nemuaron*, *Steganthera* and *Tetrasynandra*, while it is wanting in *Amborella*, *Glossocalyx*, *Piptocalyx* and *Trimenia*.

Secretory cells have again been observed in all the genera recently examined by Perkins; they are situated in the mesophyll. In view of the statement that the leaves in *Chloropatane*, Engl. are provided with transparent dots, secretory cells are probably to be found also in this genus.

3. STRUCTURE OF THE AXIS. According to Perkins the anatomical distinction between the Monimieae and Atherospermeae, based by Hobein on the breadth of the primary **medullary rays**, is on the whole supported by the results of the former's recent investigations. Thus, among the genera of the Monimieae recently examined, the medullary rays are: 2–4 seriate in *Levieria*, 1–4 seriate in *Trimenia*, 3–6 seriate in *Hennecartia*, broad in *Macropeplus* and *Macrotorus*, as in *Mollinedia*, 4–6 seriate in *Steganthera* and *Anthobembix*, 4–7 seriate in *Tetrasynandra*, and 1–2 seriate alone in *Amborella*; among the genera of the Atherospermeae recently investigated, *Nemuaron* and *Glossocalyx* have 1–3 seriate medullary rays.

Literature: [Hanausek, Folia Boldo, Zeitschr. österreich. Apotheker-Ver., 1880, p. 155; abstr. in Bot. Zeit., 1880, p. 474.]—[Stowell, Boldo leaves, Therapeutic Gazette, 1880, p. 257 et seq.; abstr. in Bot. Centralbl., 1881, i, p. 335.]—Perkins, Beitr. z. Kenntnis d. Monimiac., 1 (Mollinedieae), in Engler, Bot. Jahrb., xxv, 1898, pp. 549–53.—Perkins, *Mollinedia*, in Engler, Bot. Jahrb., xxvii, 1900, pp. 638, 639.—[Neger, Folia Boldo, Pharmaz. Centralhalle, 1901, n. 31; abstr. in Just, 1901, ii, p. 74.]—Perkins, *Siparuna*, in Engler, Bot. Jahrb., xxviii, 1901, p. 662.—Perkins and Gilg, Monimiaceae, in Pflanzenreich, Heft 4, 1901, pp. 2, 3.—Pitard, Péricycle Thèse, Bordeaux, 1901, p. 66.

LAURINEAE (pp. 702–706).

1. REVIEW OF THE ANATOMICAL FEATURES. We may add that hypoderm occurs in the leaf also in species of *Bellota*, *Endlicheria*, *Hufelandia*, *Nectandra*, *Ocotea*, *Persea*, and *Phoebe*, and that the lower epidermis shows papillose differentiation in species of *Acrodiclidium*, *Aniba*, *Endlicheria*, *Nectandra*, *Persea* and *Phoebe*.

2. STRUCTURE OF THE LEAF. Our knowledge of the structure of the leaf has been extended especially by Volker Petzold's recent investigations, which deal with the American members of the Order. According to Petzold the leaves, as a general rule, are bifacial in structure; **palisade tissue** is found on the lower side of the leaf in *Silvia* and in species of *Nectandra* and *Phoebe*, but it is never as strongly developed as on the upper side. The palisade tissue consists either of one[2] or several layers; according to Petzold the occurrence of relatively large cavities in the palisade tissue is characteristic of most of the

[1] These deal with the following genera: *Levieria*, *Amborella*, *Trimenia*, *Piptocalyx*, *Ephippiandra*, *Hennecartia*, *Nemuaron*, *Glossocalyx*, *Macropeplus*, *Macrotorus*, *Steganthera*, *Anthobembix*, and *Tetrasynandra*.

[2] There is a single layer of palisade tissue in: *Aniba* (excepting *A. robusta*, Mez and *A. Ridleyana*, Mez), *Benzoin odoriferum*, Nees, *Dicypellium*, *Endlicheria* (excepting *E. impressa*, Mez), *Sassafras*, *Silvia* (excepting *S. polyantha*, Mez), *Systemonodaphne*, *Urbanodendron*.

species of *Persea* (i.e. with the exception of three closely related species native to the Andes). The sclerosed palisade-cells previously recorded in a few species of *Ocotea* were not observed by Petzold in *Ocotea Kunthiana*, Mez, although present in *O. rubra*, Mez, where they show a somewhat different structure; Holtermann also records stone-cells in the tissue of the leaf in *Actinodaphne molochina* and *A. speciosa*. In some cases the **spongy tissue** contains large lacunae, which are filled with stellate tissue; this feature is specially pronounced in *Persea* (in contrast to almost all the species of *Phoebe*) and is found also in *Systemonodaphne* and *Urbanodendron*, as well as in species of *Acrodiclidium*, *Aniba*, *Cryptocarya* and *Misanteca*. The lateral walls of the **epidermal cells** are only rarely undulated, and particularly rarely on the upper side of the leaf. Lateral walls, which are bent in a zig-zag manner with ridge-like processes in the apices of the angles, are found in species of *Cryptocarya*, *Hufelandia*, and *Sassafras* [1] (for the most part on both sides of the leaf); high epidermal cells occur in *Bellota costaricensis*, Mez, *Endlicheria impressa*, Mez, and in species of *Aniba*, *Nectandra*, *Ocotea*, *Persea* and *Phoebe*; papillose differentiation of the lower epidermis has been observed in species of *Acrodiclidium*, *Aniba*, *Endlicheria*, *Nectandra*, *Persea* and *Phoebe* [2]. Gelatinized epidermal cells have not as yet been recorded in the Laurineae; nor are they present in *Cinnamomum Camphora*, Nees et Eberm. as I am able to state on the basis of an investigation of this species, although Tschirch and Shirasawa mention the occurrence of abundant mucilage in the epidermis of the leaf. In some species of *Ocotea*, *Persea* and *Phoebe* a marking of the cuticle has been observed in the form of a delicate punctation, but striation of the entire cuticle has not been found in any case. In the species examined by Petzold the **stomata** are again confined exclusively to the lower side of the leaf. They are, moreover, invariably accompanied by subsidiary cells, one of which is placed on either side of, and parallel to, the pore (also in *Persea indica*, Spreng., in opposition to Clauditz, loc. cit.). According to Petzold peculiar ridge-like processes are present on the pairs of guard-cells in species of *Acrodiclidium*, *Ajouea*, *Aniba*, *Cryptocarya*, *Dicypellium*, *Endlicheria*, *Misanteca*, *Nectandra*, *Ocotea* and *Phoebe*, broad subsidiary cells showing a radial striation in two closely related species of *Phoebe* (*P. Pittieri*, Mez, and *P. psychotrioides*, Mez), and depressed stomata, the pores of which are placed at right angles to the slit-shaped vestibule, formed by the subsidiary cells, in *Misanteca capitata*, Cham. et Schlecht., and most of the American species of *Cryptocarya*. On the stem of *Cassytha filiformis* the pairs of guard-cells show the same transverse arrangement as in *C. americana*. **Hypoderm** has in the first place been recorded by Petzold on the upper side of the leaf in all the species of *Cryptocarya* and *Hufelandia*, as well as in certain species of *Bellota*, *Endlicheria*, *Nectandra*, *Ocotea*, *Persea* and *Phoebe* [3]. In most cases it consists of a single layer of cells, rarely (*Bellota nitida*, *Persea boldufolia*, *Hufelandia rigida*, Mez) of two layers. Hypoderm has been observed

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[1] viz.: *Cryptocarya minutiflora*, Mez, *C. subcorymbosa*, Mez; *Hufelandia emarginata*, Mez, *H. rigida*, Mez, *H. Taubertiana*, Mez; *Sassafras variifolium*, O. K.

[2] viz.: *Acrodiclidium brasiliense*, Nees; *Aniba firmula*, Mez, *A. Gardneri*, Mez, *A. muca*, Mez, *A. Mülleriana*, Mez; *Endlicheria anomala*, Nees, *E. impressa*, Mez; *Nectandra japurensis*, Nees, *N. turbacensis*, Nees; *Persea boliviensis*, Mez, *P. carolinensis*, Nees, *P. chrysophylla*, Mez, *P. coerulea*, Mez, *P. cordata*, Mez, *P. domingensis*, Mez, *P. microphylla*, Mez, *P. racemosa*, Mez, *P. vestita*, Mez; *Phoebe cinnamomifolia*, Nees, *P. cubensis*, Nees, *P. heteropetala*, Mez, *P. mexicana*, Meissn., *P. montana*, Griseb., *P. triplinervis*, Mez.

[3] These species are: *Bellota Miersii*, Gay, *B. nitida*, Phil.; *Endlicheria Lhotskyi*, Mez, *E. sericea*, Nees; *Nectandra amplifolia*, Mez; *Ocotea aurantiodora*, Mez, *O. cuneata*, Urb., *O. daphnifolia*, Mez, *O. ferruginea*, Mez, *O. floccifera*, Mez, *O. foeniculacea*, Mez, *O. Nemodaphne*, Mez, *O. rufa*, Mez, *O. Sodiroana*, Mez, *O. spathulata*, Mez, *O. verruculosa*, Mez, *O. Wrightii*, Mez; *Persea boldufolia*, Mez, *P. crassifolia*, Mez, *P. glaberrima*, Mez, *P. Lingue*, Nees, *P. Mutisii*, H. B. K.; *Phoebe costaricensis*, Mez, *P. mexicana*, Meissn.

on both sides of the leaf only in *Hufelandia rigida*. In connexion with the earlier statements on the hypoderm, which were made on Pax's authority, we may note that this author figures hypoderm (in the 'Natürliche Pflanzenfamilien') in *Aydendron sericeum*, Griseb., and *Cryptocarya Boldus*, Mol. Holtermann records hypoderm in *Cryptocarya Wightiana*, and Dubard and Dop in *Ravensara Perrieri* sp. nov. According to Petzold the smaller **veins** are vertically transcurrent by means of sclerenchyma also in a very large number of the American members of the Order. In *Persea crassifolia*, Mez, *P. Mutisii*, H.B.K., and *P. rufotomentosa*, Nees the sheath of sclerenchyma spreads out beneath the upper epidermis, thus forming a sclerenchymatous hypoderm of one or two layers.

To the section dealing with the **oil- and mucilage-cells** (p. 703 et seq.) the following details may be added. The oil-cells are present in all the genera and species hitherto examined; in *Laurus nobilis* (according to Haberlandt) and in species of *Cinnamomum* (according to R. Müller) these elements show the same features as we have had occasion to notice in the Aristolochiaceae, &c., that is to say the secretion is enclosed in a pouch, which is suspended by means of a cuticularized 'basin.' Petzold does not record epidermal secretory cells in any of the species examined by him. The mucilage-cells, according to this author, occur either in the palisade tissue only (this being mostly the case) or in the spongy tissue only (rarely) or both in the palisade and spongy tissues. According to him they are present in *Acrodiclidium* pro parte, *Aniba* pro parte, *Bellota*, *Cryptocarya* pro parte, *Endlicheria* pro parte, *Hufelandia*, *Litsea* pro parte, *Misanteca* pro parte, *Nectandra* pro parte, *Ocotea* pro parte, *Persea* pro parte, *Phoebe* pro parte, *Pleurothyrium*, *Sassafras*, *Silvia* pro parte, *Systemonodaphne* and *Urbanodendron*, while they are wanting in *Acrodiclidium* pro parte, *Ajouea*, *Aniba* pro parte, *Benzoin*, *Cryptocarya* pro parte, *Dicypellium*, *Endlicheria* pro parte, *Litsea* pro parte, *Misanteca* pro parte, *Nectandra* pro parte, *Ocotea* pro parte, *Persea* pro parte, *Phoebe* pro parte and *Silvia* pro parte.

With reference to the mode of deposition of **oxalate of lime** we may note that the small crystals occasionally occur also in the epidermis of the leaf.

Petzold, like the earlier observers, found only unicellular clothing hairs in the **hairy covering**. A special type of hair occurs in species of *Aniba*, *Nectandra* and *Ocotea*, the body of the hair above the point of its insertion being prolonged into a lateral crop-like outgrowth. Mention may also be made of the apparently septate hairs, found in species of *Aniba*, *Endlicheria*, *Nectandra*, *Ocotea*, *Persea* and *Phoebe*; the septation depends on the fact that the lumen of the cell forming the hair disappears completely at certain points.

3. STRUCTURE OF THE AXIS. The stem of *Cassytha filiformis* shows about the same type of structure as that of *C. americana* (Schmidt, Böwig, Mirande). According to Mirande the hypocotyl and the young axis of *C. filiformis* exhibit a ring of isolated bundles in transverse section; these bundles are either fully differentiated vascular bundles or consist of phloem only. The same author states that in very old axes of this species radially elongated bands of wood are developed by the activity of cambial arcs, arising on the inner side of the groups of soft bast.

The peculiar 'cellules de marteau' described by Mirande in the endodermis of *C. filiformis*, and the lysigenous secretory spaces found in *C. americana* and *C. filiformis*, still require a special consideration; the latter resemble canals, are situated between the groups of pericyclic bast-fibres, and are filled with mucilage. The 'cellules de marteau' are particularly prominent in the young axis; they bear a blunt tip, which projects on the inner side of the endodermis, and in contrast to the other endodermal cells they contain no starch, but have abundant protoplasmic contents and a large nucleus. Their contents enable one to recognize

them also in older stems. In *C. filiformis* the mucilage-spaces above mentioned are formed as the result of the gelatinization of the walls of four or five rows of flattened cells with wide lumina (Mirande). The mucilage-cells, which occupy a subepidermal position in the primary cortex of *C. filiformis*, in some cases likewise fuse to form mucilage-canals. Mucilage-cells are present in the mesophyll of the scale-like leaves both in *C. filiformis* and *C. americana*.

A composite and continuous ring of sclerenchyma, including U-shaped stone-cells, is recorded by Pitard in the pericycle in numerous species belonging to the genera previously enumerated in this connexion, as well as in *Hufelandia pendula*. According to Hartwich the pericyclic strengthening ring in *Cinnamomum zeylanicum* becomes thrown off in older stages owing to the formation of internal cork, its place being taken by a new ring of stone-cells, which is formed for the most part from tissue belonging to the phelloderm. According to Hartwich a secondary ring of stone-cells of this kind is developed also in *Actinodaphne*, *Caryodaphne* (= *Cryptocarya*), *Haasia* (= *Dehaasia*), *Mespilodaphne*, *Ochnodaphne*, and *Tetranthera* (= *Litsea*).

Literature: Decaisne, Struct. anat. de la Cuscute et du *Cassytha*, Ann. sc. nat., sér. 3, t. v, 1846, pp. 247, 248.—Poulsen, Haustorium von *Cassytha*, etc., Flora, 1877, p. 507 et seq.—Höhnel, Gerberinden, Berlin, 1880, p. 95 et seq.—Pfister, Zimmtrinden, in Hilger, etc., Forsch.-Ber. f. Lebensmittel, i, 1894, pp. 6 and 25 et seq.—[Bastin, *Sassafras*, Americ. Journ. of Bot., 1895, p. 312 et seq.]—Biermann, Ölzellen, Diss., Bern, 1898, pp. 13–29.—[Sayre, Cinnamon barks, Drugg. Circular, etc., 1898, n. 9.]—Hartwich, Cotorinde, Archiv d. Pharm., ccxxxvii, 1899, p. 427 et seq.—Tschirch, Harzbild., Festschrift f. Schwendener, 1899, p. 464 et seq.—Hartwich, Ceylonzimmt, Vierteljahrschr. naturf. Gesellsch. Zürich, 1900, pp. 199–204.—Tschirch, Harze u. Harzbehalter, 1900, p. 387 et seq.—Hartwich, Zimmt, Archiv d. Pharm., 1901, pp. 181–201 and Tab.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 79, 80.—Siedler, Chines. Bandolinenholz, Ber. deutsch. pharm. Gesellsch., 1901, p. 20; abstr. in Just, 1901, ii, p. 99.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 297 et seq.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 17–23 (*Laurus*, *Ocotea*, *Persea*, *Phoebe*).—Gerhard, Blattanat. v. Gew. d. Knysnawaldes, Diss., Basel, 1902, pp. 28–30.—A. Th. Schmidt, *Cassytha filiformis*, Österreich. bot. Zeitschr., 1902, pp. 173–7 and Tab. vii.—Tschirch and Shirasawa, Kampher, Archiv d. Pharm., 1902, pp. 257–9.—Achner, Falsche Chinarinden, Diss., Bern, 1904, p. 30 et seq.—Böwig, *Cassytha filiformis*, Contribut. Pennsylvania Univ., Philadelphia, ii, 3, 1904, pp. 399–416, especially p. 408 et seq. and pl. 33–34.—[Kamiya, Comp. anat. of the Jap. Laurin., Bot. Magaz., Tokyo, xviii, 1904, pp. 145–56 (Japanese).]—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 11, 12, and 71, 72 (*Litsea*), pp. 84–6 and Tab. x (*Actinodaphne*), pp. 87–9 (*Cryptocarya*).—Mirande, Cassythacées, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 181–285.—R. Müller, Ölbehälter, Ber. deutsch. bot. Gesellsch., 1905, p. 297.—Piccioli, Legnami, Bull. Siena, 1906, p. 146.—Fr. Weiss, Bark in the Sassafras, Bot. Gazette, 1906, pp. 434–44.—Dubard et Dop, *Ravensara Perrieri*, Bull. Soc. bot. de France, 1907, p. 156.—Guttenberg, Immergrünes Laubblatt der Mediterranflora, in Engler, Bot. Jahrb., xxxviii, 1907, pp. 421–3 (*Laurus nobilis*).—Holtermann, Einfluss d. Klimas, 1907, pp. 119, 120.—Petzold, Syst.-anat. Untersuch. über die Bl. d. amerik. Laurin., Diss., Erlangen, 1907, 34 pp.; sep. copy from Engler, Bot. Jahrb., xxxviii.

HERNANDIACEAE (pp. 707–709).

A one-layered hypoderm is found in the leaf also in *Gyrocarpus Jacquini*, Roxb. (Holtermann). In *Sparattanthelium Tupiniquinorum* the pericycle of the axis contains isolated bundles of bast-fibres, the intervening pericyclic parenchyma only being sclerosed at certain points (Pitard).

Literature: Pitard, Diagn. anat. des div. esp. de *Gyrocarpus*, Actes Soc. Linn. Bordeaux, lvi, 1901, p. cvii; and Péricycle, Thèse, Bordeaux, 1901, p. 78.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 33–4 (*Hernandia*).—Holtermann, Einfluss des Klimas, 1907, p. 178.

PROTEACEAE (pp. 709–715).

2. Structure of the Leaf. Tassi's paper, which is cited below, contains data on the structure of the leaf and axis in species of the genera *Banksia*, *Dryandra*, *Franklandia*, *Grevillea*, *Guevina*, *Hakea*, *Isopogon*, *Leucadendron*,

Macadamia, Protea, Roupala and *Stenocarpus*[1]. We may first mention that, according to Tassi, hypoderm occurs also in *Banksia grandis*, Willd. (composed of two layers on both sides of the leaf), *Guevina Avellana*, Mol. (a single layer on the upper side), and *Stenocarpus sinuatus*, Endl. (one or two layers on the upper side, and sometimes also a single layer on the lower side), and solitary crystals of oxalate of lime in the pith of the axis also in *Guevina Avellana* and *Leucadendron argenteum*, R. Br. and in the epidermal cells of the leaf in *Hakea laurina*, R. Br. According to Francken sclerenchymatous fibres, which are connected with the sclerenchyma of the veins, are found in the mesophyll also in species of *Banksia* and *Dryandra* (*Banksia dryandroides*, Baxt., and *B. marcescens*, R. Br., *Dryandra armata*, R. Br.).

For the varied structure of the leaf in the heterophyllous species of *Hakea*, see Carlsson and Paoli, ll. cc.

3. Structure of the Axis. *Stenocarpus sinuatus* likewise shows sub-epidermal development of the cork and groups of bast-fibres in the pericycle. According to Pitard a composite and continuous ring of sclerenchyma is found in the pericycle in *Banksia ericaefolia, Grevillea brevifolia, G. buxifolia, G. macrostachya, Persoonia ferruginea* and *Rhopala Vieillardi*.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 97 et seq.—Carlsson, *Hakea Victoriae*, Bot. Centralbl., 1886, iii, pp. 77–9.—Wijnaendts Francken, Sclereiden, Diss., Utrecht, 1890, pp. 45–50.—Houlbert, Bois sec. des Proteac., Assoc. franç. Besançon, 1893, ii, publ. 1894, p. 544 et seq. (with a table for the determination of the genera).—Knoblauch, Ökolog. Anat., etc., Habilitat.-Schr., Tübingen, 1896, p. 15 et seq.—Tassi, Le Proteacee, in specie dello *Stenocarpus sinuatus*, Endl., studio anat.-morphol., Bull. Labor. ed Orto bot. Siena, i, 1898, pp. 67–134, 13 tab., especially pp. 102–19 and Tab. vii–xii.—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 65.—Paoli, Eterofillia (*Hakea suaveolens*, R. Br.), Nuovo Giorn. bot. Ital., xi, 1904, pp. 204–7 and Tab. ii.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 41, 42 (*Macadamia*).—Porsch, Spaltöffnungsapparat, Jena, 1905, pp. 126–30 and Tab. i.

THYMELAEACEAE (pp. 715–721).

1. To the Review of the Anatomical Features we may add that interxylary phloem occurs side by side with intraxylary phloem also in the genus *Brachythalamus*, which is closely related to *Gyrinops* and *Gyrinopsis*.

2. Structure of the Leaf. I have examined the structure of the leaf in *Brachythalamus caudatus*, Gilg (Beccari, n. 911, New Guinea), and may mention the following details regarding it. The leaves are bifacial in structure; isolated sclerenchymatous fibres branch off from the bast-fibres accompanying the vascular bundles of the veins and penetrate into the mesophyll; the epidermal cells are not gelatinized; the stomata, which are surrounded by ordinary epidermal cells, are confined to the lower side of the leaf, where they occur only in small numbers, and are united to form indistinct groups; the clothing hairs are unicellular; oxalate of lime, lastly, is excreted in the form of styloids, and the same is the case in the axis of *Brachythalamus podocarpus*, Gilg (Beccari, n. 299, New Guinea).

According to Keissler the 'folia albo-puncticulata' (described by earlier authors as 'glanduloso-punctata') recorded by him in the species of *Daphne*, belonging to the subsections *Oleoides, Gnidium* and *Cneorum*, as well as in *Passerina grandiflora*, L., are due to the fact that each of the stomata is surrounded by a rosette of papillose epidermal cells having a granular cuticle.

3. Structure of the Axis. In *Brachythalamus podocarpus* the xylem-mass contains: (*a*) uniseriate medullary rays; (*b*) vessels, which have rather

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[1] The plant examined by Tassi under the name of '*Persoonia myrtilloides*, Sieb.' is incorrectly determined. According to Tassi it has secretory cavities in the leaf and bicollateral vascular bundles in the petiole, so that it is a member of the Myrtaceae.

small lumina, are provided with simple perforations, and bear bordered pits in contact with parenchyma of the medullary rays; (*c*) wood-fibres, which have wide lumina and bear rather small bordered pits (bordered pits also with broadly elliptical, slit-shaped apertures); and (*d*) **interxylary phloem** (the presence of sieve-tubes has been demonstrated!). The interxylary phloem occurs abundantly even in young branches in the form of groups of varying shape; in some cases it is even found on the outer side of the groups of primary vessels; it does not include bast-fibres. At this point we may also mention that, contrary to Leisering's recent statements [1], the interxylary soft bast develops at the inner margin of the cambium (i.e. internal to the latter) in the Thymelaeaceae examined in detail by Van Tieghem.

To the section dealing with the structure of the **cortex** we may add that in *Brachythalamus podocarpus* I was able to demonstrate epidermal development of the cork and the structure of the bast, which is characteristic of the Thymelaeaceae. According to Jenčič [2] the bast-fibres of the Thymelaeaceae afford an anatomical feature, which is characteristic of the Order; their shape namely differs from the usual fusiform shape of these elements, since their ends are pointed only in very rare cases, being for the most part swollen in a clavate manner, although often truncate; enlargements and constrictions and peculiarly shaped indentations and lobes are of almost regular occurrence, being for the most part confined to one side of the bast-fibre (for details, see loc. cit.).

APPENDIX: OCTOLEPIS AND GONYSTYLUS (p. 721).

In the four new species of *Octolepis*, recently established by Gilg, he likewise demonstrated mucilage-cells in the pith and cortex, and the absence of intraxylary phloem.

Literature: [Thouvenin, Bois d'aloès et d'aigle, Journ. de Pharm. et de Chim., 1893, n. 1, 2.]—Knoblauch, Ökolog. Anatomie, etc., Habilitat.-Schr., Tübingen, 1896, p. 11 et seq.—Boergesen, Exkurs. i Sydspanien, Bot. Tidsskrift, xxi, 1897–8, pp. 143, 144 (*Thymelaea hirsuta*).—Keissler, *Daphne*, in Engler, Bot. Jabrb., xxv, 1898, pp. 34, 35.—J. Möller, Lignum aloes, Pharmaz. Post, xxxi, 1898, sep. copy, 28 pp.—Gilg, *Octolepis*, in Engler, Bot. Jahrb., xxviii, 1899, p. 141.—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, pp. 13, 14.—Petersen, Vedanatomi, 1901, pp. 53, 54 (*Daphne Mezereum*, L.).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 92.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 324 (*Gonystylus*).—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 37–9 (*Gnidium*).—Jenčič, Bastfasern der Thymelaeac., Österr. bot. Zeitschr., 1902, pp. 151–4 and 228–31.—[Armari, Piante della reg. medit., Annali di Bot., i, 1903, p. 17 et seq. (*Daphne*).]—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 160, etc.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 50.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 39–41 (*Phaleria*).—Frommel, Plantas text. chil., 1905, p. 35.—Günther, Anat. d. Myrtifloren, Diss., Breslau, 1905, p. 23.—Boorsma, Aloëholz, Bull. du Départ. de l'Agriculture aux Indes néerland., n. vii, 1907, pp. 6–19.

PENAEACEAE (pp. 722–724).

The thin-walled cells of the cork mentioned on p. 723 consist of cellulose.

Literature: Knoblauch, Ökolog. Pflanzenanat., etc., Habilitat.-Schr., Tübingen, 1896, p. 23 et seq.—Günther, Anat. d. Myrtifloren, Diss., Breslau, 1905, pp. 21, 22.

ELAEAGNACEAE (pp. 724–726).

Literature: Petersen, Vedanatomi, 1901, pp. 55, 56 (*Hippophaë rhamnoides*, L.).—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 90.—Günther, Anat. d. Myrtifloren, Diss., Breslau, 1905, pp. 23, 24.—Piccioli, Legnami, Bull. Siena, 1906, p. 178.

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[1] Leisering maintains that Van Tieghem's results are cited incorrectly on p. 720 of this book, but that is not the case; in Ann. sc. nat., sér. 7, t. xvii, 1893, it is distinctly stated that: 'ces bandes procèdent, comme le reste du bois, du bord interne de l'assise génératrice.'

[2] Species of the following genera were examined: *Cryptadenia*, *Dais*, *Daphne*, *Daphnopsis*, *Dicranolepis*, *Dirca*, *Edgeworthia*, *Gnidia*, *Lagetta*, *Passerina*, *Rhamnoneuron*, *Thymelaea*,

LORANTHACEAE (pp. 726–730).

1. Review of the Anatomical Features. In the Visceae the place of the cork is taken by a 'cuticular epithelium.' Anomalous structure of the axis in the form of concentric rings of vascular bundles occurs also in *Loranthus* sp. (Deistel, n. 77, Cameroon).

2. Structure of the Leaf. Van Tieghem's numerous publications on this Order contain scattered observations regarding the distribution of the sclereids in the mesophyll, a feature which he considers to be of primary importance, further on the distribution of the groups of silicified cells, the storage tracheids, the transversely placed stomata, &c.; we may pass over these data here as well as the detailed statements on the structure of the axis, since we may expect to find them summarized in Van Tieghem's monograph; the citation of the numerous new generic names in connexion with the anatomical features does not, moreover, appear suited to the purposes of this book. Hypoderm (composed of one or two layers) has recently been recorded by Holtermann in the leaf of *Loranthus capitellatus*; it had not hitherto been observed in this Order.

3. Structure of the Axis. In the Visceae (*Viscum, Arceuthobium, Dendrophthora, Phoradendron, Notothixos*) no cork is formed; according to Damm (for details, see loc. cit.) the epidermis at first keeps pace with the growth in thickness by stretching and division of its cells, but subsequently a 'cuticular epithelium' appears in place of the cork. This epithelium comprises cells belonging to the epidermis and primary cortex in which the outer walls have become thickened by the formation of cuticular layers.

I have casually observed the case of anomalous structure of the axis referred to above in material of *Loranthus*, belonging to the Munich herbarium (cited above). The branch, which is 1½ cm. thick, has three or four rings of growth. The groups of soft bast belonging to the individual rings of bundles are separated from one another by sclerosed medullary rays, so that in a transverse section they appear like islands, which show a concentric arrangement. The secondary vascular bundles are developed in the pericyclic parenchyma internal to a zone marked by the occurrence of groups of bast-fibres.

Literature: Van Tieghem, Numerous papers in Bull. Soc. bot. de France, 1895–6.—Boergesen og Paulsen, Veg. paa de dansk. vestind. Øer, Bot. Tidsskrift, xxii, 1898–9, pp. 107–9 (*Loranthus emarginatus*, Sw.).—Leisering, Interxyläres Leptom, Diss., Berlin, 1899, p. 13.—[Cannon, Anatomy of *Phoradendron villosum*, Bull. Torrey Bot. Club., xxviii, 1901, p. 374.]—Petersen, Vedanatomi, 1901, pp. 71, 72 (*Viscum album*, L.).—Thiselton-Dyer, Haustorium of *Loranthus aphyllus*, Annals of Bot., 1901, pp. 749–57 and pl. xl.—Van Tieghem, Rhizanthème, Journ. de Bot., xv, 1901, pp. 366, 367.—Damm, Bau mehrj. Perid., Beih. z. bot. Centralbl., xi, 1902, pp. 219–60 and Tab. i–iv.—Van Tieghem, Beccarine, Journ. de Bot., xvi, 1902, pp. 1–5, especially p. 2.—Reiche, *Phrygilanthus aphyllus*, Flora, 1904, pp. 271–97 and Tab. v.—Piccioli, Legnami, Bull. Siena, 1906, p. 175.—Holtermann, Einfluss d. Klimas, 1907, pp. 72 and 140.—[Reiche, *Phrygilanthus*-Arten, Flora, xcvii, 1907, pp. 375–401 and Tab. xiii, xiv.]—[Van Tieghem, Inovulées, Ann. sc. nat., sér. 9, t. vi, 1907.]

SANTALACEAE (pp. 730–737).

The rows of tracheides, mentioned as occurring in the leaf on p. 732, are found also in *Osyris alba*, L. (Guttenberg).

APPENDIX: 1. MYZODENDRON (p. 733).

The species having medullary vascular bundles form the subsections ***Archiphyllum*** and ***Telophyllum***, which are regarded as genera by Van Tieghem.

3. GRUBBIA (p. 737).

We may add that the periderm in *Grubbia rosmarinifolia*, Berg arises in the epidermis, and is composed of tabular cells with thin walls, and that in *G. stricta*,

DC., which belongs to the section *Ophira*, stone-cells occur in the primary cortex and numerous bast-fibres in the secondary bast (Van Tieghem).

Literature: Van Tieghem, Myzodendracées, Bull. Soc. bot. de France, 1895, p. 558.—Van Tieghem, Grubbiacées, Journ. de Bot., 1897, pp. 127-38.—Volkens, Ostafrik. Sandelholz, Notizbl. Berliner bot. Garten, etc., n. 9, 1897, pp. 272-5.—[Kusano, Haustorium of *Buckleya quadriala*, Bot. Magaz., Tokyo, xiv, 1900 (Japanese).]—Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 95.—Kusano, Parasitism of *Buckleya quadriala*, Journ. College of Sc. Imp. Univ. of Tokyo, xvii, Art. 10, 1902, 46 pp., 1 Tab.—[Barber, Haustoria of Sandal roots, Indian Forester, xxxi, 1905, pp. 189-201, pl.; abstr. in Just, 1905, ii, p. 53.]—Fraysse, Suçoirs de l'*Osyris alba*, Comptes rendus Paris, cxl, 1905, pp. 270, 271; and Parasitisme de l'*Osyris*, loc. cit., pp. 318, 319.—[Barber, Haustorium of *Santalum album*, Mem. Departm. Agr. Ind., Botany, 1906, 30 pp.]—[Pizzoni, Austori dell' *Osyris alba*, Annali di Bot., iv, 1906, pp. 79-98 and Tab. iii a.]—Guttenberg, Laubbl. d. Mediterranflora, in Engler, Bot. Jahrb., xxxviii, 1907, p. 419 (*Osyris alba*, L.).

BALANOPHOREAE (pp. 738, 739).

We may add that **stomata** have recently been observed on the scale-leaves, bracts and certain parts of the flower in *Cynomorium coccineum*, the ordinary pairs of guard-cells being accompanied by twin-stomata and stomata, in which one or both of the guard-cells are transversely divided into two cells (Pirotta and Longo).

Literature: Pirotta e Longo, Stomi nel *Cynomorium*, Rendinc. Accad. dei Lincei, viii, 1899, pp. 98-100.—Baccarini e Cannarella, *Cynomorium coccineum*, Rendinc. Accad. dei Lincei, viii, 1899, pp. 317-20 and [Atti Accad. Gioenia sc. nat. Cattania, ser. 4, xii, 1899, 60 pp., 3 Tab.].—Porsch, Spaltöffnungsapparat, Jena, 1905, pp. 69, 70.—[For further literature, see p. 1169.]

EUPHORBIACEAE (pp. 739-763).

1. The Review of the Anatomical Features requires the following additions:

The cork may occasionally develop in the pericycle.

Oxalate of lime: Styloids occur also in *Claoxylon* (incl. *Micrococca*) and *Erythrococca*; some of the idioblasts containing clustered crystals are of sub-epidermal origin, but push their way between the epidermal cells.

Internal secretory system: Elongated secretory sacs (V), like those of *Mallotus*, are found also in species of *Amanoa* and *Uapaca*, while sac-shaped secretory cells (VI), which are situated in the epidermis of the leaf and resemble those of *Ricinus*, have been observed also in species of *Bischoffia* and *Mareya*.

Trichomes: Branched multicellular clothing hairs occur in species of *Phyllanthus*, and peltate hairs also in *Crotonogyne*.

Anomalous structural features of the axis: *Lepidoturus* (Acalypheae) likewise has interxylary phloem. Cortical vascular bundles are found in certain *Euphorbias*.

The following anatomical features still deserve notice: Cork-cells, the walls of which are partly encrusted with small crystals of oxalate of lime (in species of *Croton*); fibrous cells in the primary cortex or pith, as the case may be (in species of *Angostylis*, *Conceveiba*, *Euphorbia*, and *Hyaenanche*); occurrence of palisade tissue or of large lacunae in the primary cortex (species of *Euphorbia*); strong development of the primary cortical parenchyma owing to the activity of a secondary meristem (in the Cactus-like *Euphorbias*); stomata placed transversely to the longitudinal axis of the stem (in certain *Euphorbias*).

2. Structure of the Leaf[1]. We may add the following details to the

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[1] Among the papers recently published on the systematic anatomy of this Order we may, as a supplement to the footnote on p. 741, mention Gaucher's investigations. The most important contribution is that published in Ann. sc. nat., sér. 8, t. xv. Unfortunately, however, the literature,

section dealing with the structure of the **epidermis** (p. 741). The lower epidermis of *Euphorbia pubescens* has jagged lateral walls with projections in the angles, just as in the epidermis of many petals. Gelatinization of the epidermis of the leaf is found also in species of *Baccaurea* (see Rothdauscher and Areschoug). A thick covering of wax, consisting of small rods, is found on the leaves in *Euphorbia piscatoria*, Ait., the layer of wax being interrupted above the stomata by gaps, the size of which corresponds to that of the stomata. Incrustations of wax, which show the same structure, and may be as much as 70 μ thick, also cover the epidermis of the axis in the Cactus-like Euphorbias; they are perforated above the stomata, around which they are occasionally (*E. Tirucalli*) elevated to some height in the form of a broad ring of wax. Papillose development of the epidermis of the leaf has been observed also in *Breynia disticha*, Müll. Arg. and *B. rubra*, Müll. Arg. (Phyllantheae, on the lower side), as well as in *Euphorbia Broteri*, Daveau (on both sides), *E. dendroides*, *E. flavicoma*, *E. jacquiniaeflora*, Ait., *E. Myrsinites* (on both sides), *E. nicaeensis* and *E. piscatoria*, Ait.; a many-layered **hypoderm** occurs on the upper side of the ericoid leaves of *Micranthemum ericoides*, Desf., *M. hexandrum*, Hook. f. and *Stachystemon vermicularis*, Planch. (Caletieae); a one-layered hypoderm, often composed of large cells, is present on the lower side of the leaf in the xerophilous species of *Euphorbia* (e.g. *E. Peplis*, L., *E. Preslii*, *E. aegyptiaca*). In the species of *Euphorbia* belonging to the subgenus *Anisophyllum* the **stomata** are exceptionally small. Their development in *Euphorbia* conforms either to the Ranunculaceous or Rubiaceous types; the latter type occurs quite generally among the stomata on the succulent stems of a group of species of *Euphorbia*, which are indigenous in Madagascar, and have been examined by Costantin and Gallaud. Subsidiary cells, placed parallel to the pore, are present also in *Leptonema venosum*, Juss. and *Thecacoris gymnogyne*, Pax (Phyllantheae). The pairs of guard-cells are arranged transversely to the longitudinal axis of the succulent stems in *Euphorbia Alluaudi*, Drake, *E. leucadendron*, Drake, and *E. oncoclada*, Drake, whilst in the related species the pores of the stomata lie parallel to the longitudinal axis (Costantin and Gallaud).

With reference to the **structure of the leaf** (p. 743) we may first mention that rolled leaves with a furrow to the right and left of the median vein occur also in certain species of *Cluytia*, e.g. *C. polifolia*, Jacq., *C. pterogona*, Müll. Arg., *C. pubescens*, Sond. and *C. Rustii*, Knauf (Knauf). Sclerenchymatous fibres running freely in the mesophyll are recorded by Gaucher also in species of *Glochidion* (*Phyllanthus*), the names of which are not given; 'branched sclerenchymatous cells traversing the mesophyll in a reticulate manner' are described by Koorders in *Chondrostylis bancana*, Boerl.; sclerenchymatous cells resembling rod-cells by Areschoug in the palisade tissue of *Excoecaria Agallocha*,

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apart from Pax's paper (in Engler's Jahrb., v), is not taken into consideration by Gaucher, so that it will be necessary to reinvestigate those statements, which are contradictory to the earlier ones, especially those referring to the occurrence of receptacles for water-storage (loc. cit., pp. 217, 218; some of these are probably gelatinized epidermal cells) and the duplication of the epidermis (loc. cit., pp. 219, 220, as well as p. 295, gelatinized epidermal cells?) in the leaf, and statements dealing with the secretory organs and the intraxylary soft bast. Gaucher also determined the anatomical features in a large number of genera, which had not previously been examined, and has thus advanced our knowledge of the anatomy of the Euphorbiaceae. These genera are as follows (arranged under the tribes distinguished by Müller-Arg.): i. Caletieae: *Micrantheum*, *Stachystemon*. iii. Ampereae: *Monotaxis*. iv. Phyllantheae: *Agyneia*, *Buraeavia* (not enumerated in Müller-Arg.'s system), *Choriophyllum* (not enumerated in Müller-Arg.'s system), *Cyathogyne*, *Hyaenanche* (*Toxicodendron*), *Leptonema*, *Maesobotrya* (not enumerated in Müller-Arg.'s system), *Pseudolachnostylis*, *Reverchonia*, *Sibangea* (not enumerated in Müller-Arg.'s system), *Thecacoris*, *Uapaca*. v. Bridelieae: *Cleistanthus*. vii. Acalypheae: *Alchorneopsis*, *Angostylis*, *Crotonogyne*, *Erythrococca*, *Haskarlia*, *Lasiocroton*, *Leidesia*, *Lepidoturus*, *Manniophyton*, *Mareya*, *Mischodon*, *Neoboutonia*, *Platygyne*, *Pycnocoma*. viii. Hippomaneae: *Bennettia* (*Galearia*), *Cheilosa*, *Omphalea*. x. Euphorbieae: *Anthostema*, *Pedilanthus*, *Synadenium*.

Müll. Arg.; and enlarged terminal tracheids by Gaucher in *Amanoa oblongifolia*, Müll. Arg. and certain species of *Euphorbia* (e.g. *E. Broteri*, *E. Myrsinites* and *E. splendens*). In *Discocarpus* (e.g. *D. Spruceanus*, Müll. Arg.) and *Bridelia micrantha*, Müll. Arg. Gaucher describes and figures sclerenchymatous plates, which traverse the mesophyll in the vertical direction and, according to him (loc. cit., pp. 210, 211), do not include any vascular elements; in all probability, however, they are merely veins, which are vertically transcurrent by means of sclerenchyma.

According to Gaucher, the sheath of large parenchymatous cells with wide lumina, previously recorded in certain species of *Euphorbia* (in the section dealing with the structure of the **veins**, p. 744), is a feature characteristic of those species of the genus which belong to the subgenus *Anisophyllum*. Similar sheaths of wide parenchymatous cells containing tannin accompany the sclerenchyma of the veins in species of *Amanoa*, *Discocarpus* and *Pseudolachnostylis*. There is a complete absence of sclerenchymatous tissue accompanying the veins in the *Euphorbias*.

According to Gaucher, **oxalate of lime** (cf. pp. 744–6) is found in the form of styloids (in cells which traverse the entire thickness of the mesophyll) also in *Claoxylon* (*C. affine*, Zoll. and other species), as well as in *Micrococca Mercurialis*, Benth. (*Claoxylon Mercurialis*, Thw.; this record is not in agreement with Rittershausen's earlier statement) and *Erythrococca* (*E. aculeata*, Benth. and *E. capensis*, Müll. Arg.). The results of Knoll's work have shown the necessity for a reinvestigation of the course of development of the crystal-cells in the case of the earlier statements on the occurrence of clustered crystals in the epidermis, or at least in the case of some of them; the object of the reinvestigation being to determine whether these elements really belong to the integumental tissue or whether we are concerned with cells (containing clustered crystals) of the subepidermal layer, which push their way in between the epidermal cells or even extend beyond them; the second alternative applies to *Dalechampia Roezliana*, Müll. Arg. (probably also to other Acalypheae) as well as to the hairs containing clustered crystals found in *Plukenetia* and *Fragariopsis* (see below).

Cells, which contain clustered crystals and are either actually or apparently situated in the epidermis, are recorded by Gaucher also in species of *Securinega* (*Flüggea*, Phyllantheae), *Bridelia* (where there are small groups of cells containing oxalate of lime), *Crotonogyne* and *Manniophyton* (Acalypheae), and species of *Jatropha* (not mentioned in Herbert's paper; Hippomaneae).

According to Gaucher, the crystalline bodies, found in *Euphorbia splendens* (see p. 746) and regarded by Pax as crystals of abietinic acid, consist of oxalate of lime, which is absent in other species of *Euphorbia*. For the sphaerites of calcium phosphate and calcium malophosphate occurring in the Cactus-like *Euphorbias*, see also Gaucher; and regarding the colouring-matter (which produces a blue tint) in dried plants of *Mercurialis*, see Fructus, loc. cit. The former are found also in certain *Euphorbias*, which do not have a cactoid habit (e.g. *E. atropurpurea* or *E. Lathyris*), as well as in *Pedilanthus carinatus*. The strongly refractive (silicified ?) bodies, observed by Knauf on the walls of the epidermal cells in the isothermous species of *Cluytia*, as well as in other species of this genus, still require closer investigation (cf. Herbert, Diss., p. 24).

To the section dealing with the **secretory elements** of the Euphorbiaceae (p. 746 et seq.) the following details may be added :—

1 **Laticiferous cells.** As regards the distribution of these elements we may note that, contrary to Herbert, Gaucher records them in *Cluytia*; he likewise mentions their occurrence in *Omphalea*, which belongs to the same Tribe (Hippomaneae), and the genera *Anthostema*, *Pedilanthus* and *Synadenium* (Euphorbieae). The laticiferous tubes have been observed to penetrate into

the mesophyll also in *Julocroton*. In *Euphorbia* and *Macaranga* they often have very wide lumina and are surrounded by a sheath of small cells containing starch, so that they appear like secretory canals. The 'reticulate anastomoses' described by Mayus in the mesophyll of *Euphorbia Lathyris* are, no doubt, the result of incorrect observation [1]. Molisch records rod-shaped starch-grains in the contents of the laticiferous cells also in *Hippomane biglandulosa*, Aubl. and *Pedilanthus tithymaloides*, Poit., crystalloids, not only in *Jatropha Curcas*, but also in *J. glauca*, Hort., *J. gossypiifolia*, L. and *J. podagrica*, Hook., peculiar spherical elaioplasts in *Homalanthus populneus*, Pax, and an accumulation of magnesium in the latex of *Euphorbia mammillaris*.

IV. The laticiferous or **tanniniferous elements** comprised in this section are likewise considered in Gaucher's work. He distinguishes between rows of secretory cells of equal length (Type '*Acalypha*') and rows of secretory cells of unequal length (Type '*Macaranga digyna*, Müll. Arg.' with rather long and rather short cells, and Type '*Alchornea cordata*, Müll. Arg.' with very long and very short cells); the division-walls between the cells may or may not be resorbed. Renewed investigations both on a developmental and on a systematic anatomical basis are required to enable us once and for all to obtain a clear conception of the nature and systematic value of these secretory organs.

V. According to Gaucher, the wide-lumened **secretory sacs** of *Mallotus* (*M. ricinoides*, Müll. Arg.), which were referred to under Section V, arise from a cylindrical complex of irregularly arranged cells containing secretion; the same mode of origin is ascribed to the tanniniferous sacs of a similar type which are found in *Amanoa* '*javanica*, Miq.' (Zollinger, n. 1662, Java) and *Uapaca Heudelotii*, Baill.

VI. The tubular **secretory cells** present in the epidermis of the leaf in *Ricinus communis*, Müll. Arg. may be associated with (*a*) similar epidermal secretory cells which occur in *Bischoffia* (according to my own observation, Hippomaneae), although in this case they are provided with undulated lateral walls like the remaining epidermal cells, and (*b*) tanniniferous elements with wide lumina occurring in the lower epidermis of *Mareya brevis*, Pax (according to Gaucher, Acalypheae). In this connexion we may also note that a few enlarged tanniniferous cells occasionally occur in the palisade and spongy tissues (e.g. in the palisade tissue of *Andrachne cordifolia*, Müll. Arg.), that a layer of tanniniferous cells is situated beneath the typical palisade layer in *Crotonogyne Zenkeri*, Pax, and a similar one in the spongy tissue in *Caperonia cordata*, St. Hil.

VII. **Intercellular secretory receptacles** like those previously recorded have been found in the following additional cases: in the primary cortex of *Cluytia hirsuta*, Müll. Arg. (according to Pax); in the primary cortex of *Cluytia alaternoides*, Müll. Arg. (cf., however, p. 752) and *C. pulchella*, Müll. Arg. (according to Gaucher); and in a subepidermal position in the branches and scale-leaves of *Hura crepitans*, L. (according to Gilles).

To the subsequent paragraphs, which deal with the hairy covering (p. 752 et seq.) the following data regarding the **clothing hairs** (see under I) may first be added. Little branched clothing hairs occur in species of *Phyllanthus*, the names of which are not given. Peltate hairs are found also in *Crotonogyne*, and sclerenchymatous columns, connecting the trichomes on the two sides of the leaf, also in *Julocroton montevidensis*, Klotzsch.[2]

II. **Glandular hairs.** The extrafloral nectaries (see p. 755) have recently been examined in detail in *Excoecaria* (by Poulsen), *Hevea* (by Daguillon and

[1] One certainly does meet with H-shaped connexions, which may be explained as due to branching, but there are no typical reticulate anastomoses.

[2] The plant examined by Areschoug (1905) and described as *Bridelia tomentosa*, Bl. with a query, bears unicellular two-armed trichomes and probably does not belong to the genus *Bridelia*.

Coupin and also by Parkin) and *Macaranga* (by Smith). They resemble the glands of *Ricinus*, &c. and the glands occurring on the cyathium (see Gaucher) in having a secretory palisade epidermis. In *Excoecaria biglandulosa*, Müll. Arg. this epidermis clothes a slit-shaped canal in the peg-shaped nectary, which lies at the base of the lamina. Both in *Hevea brasiliensis*, Müll. Arg. and in *H. Spruceana*, Müll. Arg. the nectaries are situated at the apex of the petioles of the foliage-leaves and are accompanied by bud-scales, some of which are entirely transformed into nectaries; the upper epidermis of these bud-scales is more or less completely modified to form a secretory palisade tissue, which for the most part consists of a single layer of cells, but at certain points is composed of two or three layers. Smith mentions the occurrence of multicellular glandular structures, which are stated to be of the nature of food-bodies, on the stipules of the myrmecophilous species *Macaranga triloba*.

III. The earlier statements regarding the **stinging hairs** (discussed under Section III, pp. 756, 757), which are found in the genera *Cnesmone*, *Leptorhachis*, and *Tragia* of the Acalypheae, as well as in *Dalechampia*, require a considerable amount of correction as a result of Knoll's work. This author in the first place examined the structure and course of development of the stinging hairs, found in *Dalechampia Roezliana*, Müll. Arg. var. *rosea*; the hairs of this plant correspond to those shown in Fig. 180, *Q* on p. 748, although the latter have a more complicated structure. The investigation has brought to light the fact that the outer part of the pedestal in these hairs consists of 3–5 epidermal cells, which are elevated above the surface to a considerable extent and envelop an elongated central cell, which, as its mode of development shows, does not belong to the epidermis, but arises subepidermally; the pointed end of the central cell, which contains the crystal of oxalate of lime, projects far beyond the limits of the pedestal. The 'middle cell' and 'terminal cell' previously mentioned are thus but a single cell, which, moreover, belongs to the subepidermal layer and not to the epidermis. Similarly, the unicellular stinging hairs, figured for *Tragia cissoides* in Fig. 180, *P*, are subepidermal cells, which have pushed their way in between the epidermal cells and thereupon project far beyond the level of the epidermis like true unicellular (epidermal) hairs; such cases necessitate a corresponding extension of the definition of what is briefly styled a 'hair.'

Since the lower end of the crystal, which is suspended in the upper part of the central cell, is provided with a pair of teeth, we are justified in regarding it as a reduced clustered crystal in which only one of the projecting ends of the individual crystals is strongly developed. Moreover, inasmuch as the crystal-cells (with clustered crystals), which are situated in the epidermis of the leaf of *Dalechampia Roezliana*, belong to the subepidermal layer (see above, p. 1049)—a fact which has likewise been determined by Knoll—it is more than probable that the crystal-cells (containing clustered crystals) supposed to have been demonstrated in the epidermis of other members of the Acalypheae (and perhaps even of other Euphorbiaceae in which they occur) are likewise of subepidermal origin; this applies especially: (*a*) to the cells containing clustered crystals found in *Caperonia* and *Argyrothamnia*, the cells in question projecting somewhat after the manner of a hair; (*b*) to the cells containing sphaerites found in *Acalypha* and *Claoxylon*, which likewise project beyond the surface; and (*c*) to the hairs with clustered crystals occurring in *Fragariopsis* and *Plukenetia* (see Fig. 180, *S*). The cells with clustered crystals found in *Caperonia* and *Argyrothamnia*, and the hairs with clustered crystals constitute transitional forms (or, if one prefers, developmental forms) to the typical stinging hairs of *Dalechampia*, &c.

In accordance with the preceding statements I agree with Knoll also in the changed interpretation of the structure of the crystal-hairs (containing clustered crystals), which are found in *Fragariopsis* and *Plukenetia*. The 'epidermal cell, which is differentiated as a papilla or short hair, and contains a clustered crystal, the spines of which are all directed outwards' and the 'narrow

cell, which penetrates to a considerable depth in the mesophyll' (see the previous description, p. 757), form but a single cell, which is identical with the central cell of the stinging hair. The division-wall, shown in Fig. 180, *S*, belongs to the cellulose-sheath enveloping the clustered crystal.

For the structure of the stipular **spines** of *Euphorbia splendens* and *E. lactea*, see Mittmann and Barber, ll. cc.; for the prickly structures found on the axes of *Hura crepitans* and caused by the prick of an insect, see Didrichsen, loc. cit.

The **petiole** in this Order has hitherto been investigated only in a very inadequate manner, especially in view of the large size of the Order. New details regarding its structure will be found in Gaucher's work (see Ann. sc. nat., 1902). According to this author, the petiole in the species of *Euphorbia* belonging to the subgenus *Anisophyllum* contains a single vascular bundle, while in the remaining species of the genus there are three or four isolated bundles.

3. Structure of the Axis. To the list of Acalypheae, which possess **intraxylary phloem** (see p. 757), we may, on Gaucher's authority, add *Lepidoturus* (*L. alnifolius*, Baill. and *L. laxiflorus*, Benth.) and *Mallotus subulatus*, Müll. Arg.[1]

Cortical vascular bundles are recorded by Kniep in *Euphorbia Cyparissias* and *E. orientalis*.

The following details may be added to the earlier account of the development of the **cork**. In *Euphorbia antiquorum* and *E. piscatoria* the cork-cambium arises in the inner layer of the two-layered epidermis; in *Phyllanthus Welwitschianus*, Müll. Arg. it develops in the second or third layer, in *Mischodon zeylanicus*, Thw. in the third or fourth layer, and in *Baccaurea racemosa*, Müll. Arg. on the inner side of the sclerenchymatous fibres of the pericycle. In some cases the place of origin of the cork varies within certain limits in different parts of the branch of one and the same species (for details, see Gaucher). According to Gaucher, the cork in *Croton gratissimus*, Burch. contains crystals of oxalate of lime, while in *Ditaxis fasciculata*, Juss. it includes fibrous cells with thick walls. Records of the occurrence of crystals of oxalate of lime in the cork will be found also in the pharmacognostic works of A. Meyer and others, the data referring to Cortex Cascarillae, which is derived from *Croton Eluteria*, Benn.; the descriptions, however, are inexact. According to my own investigation the cork-cells of the Cascarilla-bark, even in the young branches, have strongly thickened outer tangential walls, while the inner tangential walls and the radial walls are relatively thin; the inner tangential walls and the adjoining parts of the radial walls are encrusted with small rhombohedral or variously shaped crystals of oxalate of lime, and after the solution of the latter by means of hydrochloric acid, those parts of the wall, which were previously encrusted, show a network in relief corresponding to the insertion of the crystals. I have found an exactly similar type of incrustation, which affects the same parts of the cell-wall, in the cork-cells (which here have relatively thin walls and wide lumina) of the Copalche-bark, which is obtained from *Croton niveus*, Jacq. The distribution of this highly peculiar type of cork within the genus *Croton* is worthy of a more detailed investigation; it makes its presence noticeable even in the external aspect of the plant owing to the white colour of the cork. A feature not hitherto recorded is the occurrence of fibrous cells in the **primary cortex** and pith. According to Gaucher they are found in the primary cortex in *Hyaenanche* (*Toxicodendron*) *globosa*, Lamb. et Vahl (scattered elements with thick walls),

[1] The species of *Euphorbia*, included by Gaucher (in Ann. sc. nat., 1902, loc. cit., p. 196) in the 'Type *Euphorbia*' and 'Type *Tragia Okanyua*, Pax,' are stated by him to have weakly developed strands of internal soft bast; in all these cases, however, we are probably concerned with unlignified elements belonging to the innermost parts of the xylem.

Conceveiba guianensis, Aubl. (slightly thickened and arranged in groups), *Angostylis longifolia*, Benth. (slightly thickened and forming a peripheral zone), and *Euphorbia xylophylloides*, which has the habit of a Cactus (isolated elements, here also in the pith); according to Costantin and Gallaud (see also Fron), fibrous cells occur also in a group of succulent species of *Euphorbia* found in Madagascar (elements with thick stratified walls; confined to the primary cortex in *E. Geayi*, Cost. et Gall., *E. Intisy*, Drake, *E. Laro*, Drake, *E. rhipsaloides*, Lem. and *E. Tirucalli*, L.; present both in the pith and primary cortex in *E. alcicornis*, Bak., *E. Alluaudi*, Drake, *E. arsoides*, Cost. et Gall., *E. Decorsei*, Drake, *E. enterophora*, Drake, *E. leucadendron*, Drake, *E. oncoclada*, Drake, and *E. stenoclada*, Baill.). In the leafless species (e.g. *Pedilanthus aphyllus*, Boiss., *Calycopeplus ephedroides*, Planch. and species of *Euphorbia*) the primary cortex contains palisade tissue. In species frequenting a marshy habitat (e.g. *Euphorbia palustris*) large lacunae are found both in the primary cortex and in the pith. In the Cactus-like *Euphorbias* the primary cortex is particularly strongly developed, the cortical tissue in these forms undergoing continual increase by means of a peripheral meristematic zone. The **pericycle** is developed in the form of a composite and continuous ring of sclerenchyma, including stone-cells with U-shaped thickening, also in *Savia erythroxyloides*, Griseb.

DAPHNIPHYLLACEAE (p. 760).

The lower epidermis of the leaf includes groups of small cells containing clustered crystals of oxalate of lime also in *Daphniphyllum bancanum*, Kurz and *D. laurinum*, Baill.

BUXACEAE (pp. 761–763).

To the second paragraph, summarizing the features which are uniform throughout the group, we may add the following details. The cork develops in the pericycle in later stages also in *Buxus*, the superficial formation of the cork in this case being merely a local phenomenon. Secretory cells are found also in *Buxus* (*Eubuxus*). The anomalous structure of the vascular system, previously described in *Simmondsia* (which Van Tieghem regards as being related to the Tetragonieae), occurs not only in the stem, but also in the root. Cortical vascular bundles are found in the old-world species of *Buxus* (*Eubuxus*, Baill.) and in *Notobuxus natalensis*, Oliv., but not in the American species of the genus (*Tricera*, Sw., as a genus).

The structure of the **leaf** is bifacial also in *Styloceras*. It is a remarkable fact that the lower half of the **mesophyll** of the more or less distinctly bifacial leaves has a dense structure in all cases, except in the species of *Buxus* belonging to the section *Eubuxus*. Typical spongy tissue with large lacunae, which directly adjoin the assimilating tissue (this latter being either of the nature of palisade or consisting of rounded cells) and are the cause of a splitting of the leaf into two halves, is found in the species of *Eubuxus* (e.g. in *Buxus sempervirens*, L.); the two halves of the leaf are in connexion with one another only at the margin of the lamina; the process of splitting takes place in the living leaf at a time when it has not yet attained its full size, and is not merely a result of the drying of the leaf. The earlier statement to the effect that **oxalate of lime** is wanting in the leaf of *Buxus sempervirens* is incorrect; clustered crystals occur in the mesophyll and ordinary solitary crystals accompany the vascular bundles of the veins, and in addition to that one finds a peculiar kind of crystal-sand, composed of relatively large prismatic crystals, which occasionally have a corroded appearance. The cells containing this crystal-sand give rise to the small white dots, which are visible even to the naked eye along the median vein on the lower side of the leaf. **Secretory cells** are present also in the mesophyll of *Buxus sempervirens*, and Van Tieghem has likewise observed them in the mesophyll and primary cortex of *B. balearica*, Willd. and in the primary cortex of *Simmondsia*. The secretory cells of *Buxus sempervirens* show up prominently in the palisade tissue owing to their large size and in the spongy tissue owing to a reduction in the development of the arms; their bright contents, which are strongly refractive (in the living leaf), are insoluble in water and alcohol and assume a deep brown colour on treatment with a solution

of Iodine. Clothing **hairs** are found also in *Buxus*; in *B. sempervirens* they are uniseriate and composed of two or more cells with thick walls, while in *B. acuminata*, Müll. Arg. and *B. Hildebrandtii*, Baill., for instance, they are unicellular. Boergesen and Paulsen's statement as to the occurrence of deeply sunk external glands on the leaf of *B. Vahlii*, Baill. ('*Tricera laevigata*, Sw.') requires closer investigation.

In *Pachysandra*, *Sarcococca* and *Styloceras*, the American species of *Buxus* (*Tricera*), *Notobuxus natalensis*, Oliv. and the African species of *Buxus* (*B. Hildebrandtii*, Baill., *B. Mac-Owani*, Oliv., *B. madagascarica*, Baill., *B. pedicellatus*, Van. Tiegh.) the **petiole** contains three vascular bundles, viz. a large median bundle and two smaller lateral ones; in *Notobuxus* and in the American and African species of *Buxus* these lateral bundles form the marginal vein of the leaf. On the other hand, in the European and Asiatic species of *Buxus* belonging to the section *Eubuxus* (which in accordance with Van Tieghem's investigations is better restricted to include only the species just mentioned, the above-named African species of *Eubuxus* being best classed with *Notobuxus*) the petiole contains only a single vascular bundle, which is accompanied on either side by a strand of fibres. The petiole of *Simmondsia* contains an arc-shaped vascular bundle, which soon becomes closed to form a ring.

The distribution and general course of the **cortical vascular bundles** of *Buxus* has been determined by Van Tieghem's recent investigations. Cortical bundles are found in all the European, Asiatic and African species of *Buxus*, as well as in *Notobuxus natalensis*, but do not occur in the American species of *Buxus* (*Tricera*); as in the case of *B. sempervirens* the bundles are four in number and show normal orientation of their wood- and bast-groups. In the European and Asiatic species of *Buxus* the bundles are supported by a strand of bast-fibres situated on their outer side (i.e. adjoining the bast); whereas groups of mechanical fibres have been observed on the inner side of the bundles (i.e. next to the wood) only in occasional species (e.g. in *B. balearica*, Willd. and *B. japonica*, Müll. Arg.). In *Notobuxus natalensis* and the African species of *Buxus*, on the other hand, the xylem is invariably surrounded by a group of mechanical fibres, but there are no fibres adjoining the bast. The cortical strands branch off from the two bundles, which pass out from the vascular ring at the node to supply the two opposite leaves; these branches run in the following internode, and ultimately end blindly. In the European and Asiatic species of *Buxus* the groups of fibres situated on the outer side of the cortical vascular bundles are continued into the petiole, where they appear at the sides of the single vascular bundle (see above). On the other hand, in *Notobuxus* and the African species of *Buxus* this is not the case; the three vascular bundles present in the petiole of these species are formed by the branching of the single bundle, which bends out into the leaf from the vascular ring of the axis; the three vascular bundles in the petiole of the species of *Buxus*, belonging to the section *Tricera*, arise in the same way.

The **primary cortex** contains cells showing U-shaped thickening also in *Buxus acuminata*, while slightly sclerosed cells occur quite generally in this tissue in the African species of *Buxus* and in *Notobuxus*. Such sclerosed cells are found in certain African species of *Buxus* also in the pith, bast and pericycle. The pericycle includes isolated groups of bast-fibres in *Styloceras*, and a few bast-fibres in *Buxus longifolia*, Müll. Arg.; in *Buxus* the pericycle is generally parenchymatous. Oxalate of lime occurs in the cortex of *Buxus* also in the form of clustered crystals.

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BALANOPSEAE (pp. 763, 764).

A composite and continuous ring of sclerenchyma is found in the pericycle also in *Balanops oliviformis*, and has been observed in an undetermined species even in branches of 55 mm. thickness[2].

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[1] The plant described by Clauditz (loc. cit., pp. 40, 41) as *Mercurialis ambigua* (which has raphides, brown secretory cells, and stomata with parallel subsidiary cells) is incorrectly determined and does not belong to the Euphorbiaceae. Judging by the anatomical characters it may possibly be a member of the Rubiaceae.

[2] Pitard, Péricycle, Thèse, Bordeaux, 1901, p. 77.

URTICACEAE (pp. 764–779).

To the brief Review of the Anatomical Features of the Urticaceae taken as a whole (p. 764), we may add that laticiferous cells have been recorded also in the second genus (*Cannabis*) of the Cannabineae, that elements resembling laticiferous tubes occur also in the genus *Urera* (Urticeae) and that raphides and styloids have recently been observed in the genus *Laportea* (Urticeae).

1. ULMACEAE (pp. 764–768).

A composite and continuous ring of sclerenchyma is developed in the pericycle also in *Sponia rugosa* (= *Trema rugosa*) (Pitard).

2. CANNABINEAE (pp. 769, 770).

Laticiferous cells are stated to occur also in *Cannabis*. Tschirch at least regards the secretory elements, which are present in the secondary cortex as well as in the soft bast of the veins of the leaf, as laticiferous cells; they are tubular elements with rather wide lumina, which in the drug are occupied by brownish contents. According to Molisch, the latex of the hop is rich in tannin; it also contains colourless spherical or biconvex grains, which recall the protein-grains found in *Cecropia* and *Brosimum*.

3. MORACEAE (pp. 770–775).

We may add the following details to the Review of the Anatomical Features. Laticiferous cells occur in the leaves in all the Artocarpeae, being found especially in the veins and sometimes even in the mesophyll itself, whilst in the Conocephaleae the laticiferous cells are almost confined to the axis and only rarely penetrate into the lamina of the leaf. The glandular hairs found in the Artocarpeae and Conocephaleae vary in structure (see below). With the glandular hairs we may associate large wax-glands, which are provided with a palisade-epithelium, and occur in many species of *Ficus*; the mucilage-canals of the Conocephaleae are accompanied by rows of mucilage-cells, which are found in the veins of the leaf. Tanniniferous idioblasts have been observed also in genera other than those previously mentioned in this relation. Oxalate of lime occasionally occurs also in the form of small crystals of varied shape. To the previous enumeration of the special features presented by the structure of the leaf (e.g. occurrence of hypoderm and clustered crystals in the epidermis, which have now likewise been shown to have a wider distribution) we may add: the occurrence of division-walls in the epidermis; papillose differentiation of the epidermis; gelatinization of the inner walls of epidermal cells; stomatal groups and stomata situated in pits (*Ficus*); hydathodes provided with an epithema; arm-palisade tissue (*Parartocarpus*); spicular fibres (*Balanostreblus, Ficus, Sahagunia*); occurrence of solitary crystals in the epidermis.

A detailed investigation of the Structure of the Leaf (see p. 770) had not till recently been carried out, but has since been undertaken by Renner[1] in

[1] Renner's investigations deal with the following genera: 1. Artocarpeae: *Ficus, Sparattosyce, Dammaropsis, Brosimum, Lanessania, Bosqueia, Scyphosyce, Antiaris, Olmedia, Pseudolmedia, Castilloa, Helicostylis, Perebea, Helianthostylis, Cudrania, Poulsenia, Treculia, Parartocarpus* (incl. *Gymnartocarpus*), *Artocarpus* (incl. *Prainea*), *Brosimopsis, Sahagunia, Balanostreblus, Sorocea*; 2. Conocephaleae: *Cecropia, Myrianthus, Musanga, Coussapoa, Conocephalus* (incl. *Balansaephytum*), *Pourouma*.

the tribes Artocarpeae and Conocephaleae. The following pages are, in the main, a summary of the results of his work. The upper **epidermis** in many cases consists of a single layer of cells, but it is frequently 2- or 3-layered at certain points or almost throughout. Only a small number of epidermal cells divided by tangential walls are found in *Antiaris saccidora*, Dalz., *A. toxicaria*, Lesch., *Castilloa elastica*, Cerv., and *Myrianthus arboreus*, P.B.; the upper epidermis is two-layered in *Cecropia obtusifolia*, Bertol., *C. scabra*, Mart., and in numerous species of *Ficus*, while it is 2–3-layered in *Dammaropsis Kingiana*, Warb. The same feature has been observed in the lower epidermis, although it is of rare occurrence (*Conocephalus tonkinensis*, Renn., *Ficus longifolia*, Schott and *F. gibbosa*, Bl.). Regarding the distribution of the **hypoderm** we may mention the following details on Renner's authority: it occurs on the upper side of the leaf in *Cecropia* and *Sahagunia* (here one-layered), *Artocarpus*, *Balanostreblus* and *Pourouma* (one- or two-layered), *Coussapoa* and *Musanga* (2-layered), *Conocephalus* (2–3-layered) and *Ficus* (1–4-layered); in *Ficus* it is present also on the lower side of the leaf, where it consists of two or three layers. The species in which hypoderm has been recorded are enumerated below[1] (excepting the numerous species of *Ficus*; see also Holtermann, loc. cit.). The hypoderm is almost invariably parenchymatous, but apart from that, its cells vary in size, in the nature of their lateral walls, and in the general structure of the walls. A fibrous hypoderm, which consists of four layers and probably belongs to the ground-tissue, is found beneath the upper epidermis in *Artocarpus lanceaefolius*, Roxb., this feature going hand in hand with the vertical transcurrence of the weaker lateral veins by means of sclerenchyma; transitions to this type of structure occur also in other species of *Artocarpus*. The development of the hypoderm from the dermatogen has hitherto been demonstrated only in certain species of *Ficus*. Other noteworthy features in the structure of the epidermis are as follows: the septation of epidermal cells by thin vertical walls (species of *Artocarpus*, *Brosimopsis* and *Poulsenia*); cuticular elevations in the form of delicate parallel striae (species of *Ficus* and *Parartocarpus*), or of coarse crests, showing an irregular arrangement (*Ficus crocata*, Mart. and allied species), these two characters occurring especially on the lower side of the leaf; and the presence of one or two peculiar thickenings shaped like a biconvex lens on the outer walls in *Ficus paraënsis*, Miq., these walls perhaps serving for the perception of light. Papillae are not very commonly formed on the lower side of the leaf. Variously differentiated papillae are found in all the species of *Brosimum* examined by Renner, and also in *Ficus foveolata*, Wall., *F. pumila*, L., *Helicostylis Poeppigiana*, Tréc., and *Myrianthus arboreus*, P.B. Gelatinization of the integumental tissue has not been demonstrated in any species of *Ficus*, but cells with mucilaginous inner membranes occur in the upper epidermis in species of *Antiaris*, *Artocarpus* (in *A. Vrieseanus*, Miq. in the lower epidermis as well), *Bosqueia*, *Brosimopsis* (here the outer wall is also mucilaginous), *Brosimum*, *Cecropia*, *Helicostylis*, *Olmedia*, *Perebea*, *Pseudolmedia*, and in the hypoderm on the upper side of the leaf in species of *Balanostreblus*, *Cecropia*, *Conocephalus*, *Coussapoa* and *Musanga*. In *Artocarpus dasyphyllus*, Miq. and other species of *Artocarpus* belonging to the section *Pseudojaca* certain of the upper epidermal cells have strongly thickened inner walls, which only swell up to a slight extent in water and assume a yellow colour on

[1] *Artocarpus Blumei*, Tréc., *A. Kemando*, Miq., *A. Maingayi*, King, *A. Tamaran*, Becc.; *Balanostreblus ilicifolia*, Kurz; *Cecropia adenopus*, Mart., *C. Humboldtiana*, Klotzsch, *C. latiloba*, Miq., *C. leucocoma*, Miq., *C. mexicana*, Hemsl., *C. peltata*, L., *C. sciadophylla*, Mart.; *Conocephalus lanceolatus*, Tréc., *C. suaveolens*, Bl., *C. tonkinensis*, Renn.; *Coussapoa intermedia*, Mart., *C. nitida*, Miq., *C. Schottii*, Miq., *C. subincana*, Mart., *C. villosa*, Poepp. et Endl.; *Musanga Smithii*, R. Br.; *Pourouma acuminata*, Mart., *P. bicolor*, Mart., *P. cecropiaefolia*, Mart., *P. cinerascens*, Miq., *P. fuliginea*, Miq., *P. tomentosa*, Mart., *P. velutina*, Mart.; *Sahagunia Peckoltii*, K. Sch.

treatment with Iodine-solution and Sulphuric acid. Silicification of the walls of the epidermal cells, especially of the outer walls, is very common.

The **stomata** in the Artocarpeae and Conocephaleae are found almost exclusively (exception : *Cecropia Humboldtiana*, Klotzsch) on the lower side of the leaf. In some cases (species of *Cecropia, Coussapoa, Pourouma*) they are placed on pedestals, formed by the neighbouring cells, while in *Brosimopsis lactescens*, Sp.-Moore and certain species of *Ficus* they are sunk below the surface. Distinct subsidiary cells, conforming to the Cruciferous type, are present only in *Conocephalus*. Apart from that, a rosette of subsidiary cells, distinguished by having thinner walls, is found in *Ficus Binnendijkii*, Miq. and *F. pertusa*, L. f. Owing to the projecting network formed by the veins on the lower side of the leaf, and a corresponding differentiation of the lower epidermal cells, the stomata with their neighbouring cells are frequently (especially in many species of *Ficus*) found to be arranged in groups in the meshes between the veins; the meshes themselves are often depressed to form small pits. Typical stomatal groups, however, occur only in *Ficus gibbosa*, Bl. In this connexion we may also notice the stomatal pits found in certain species of *Ficus*, and visible to the naked eye as spots on the surface of the leaf; they have been described in detail by Bargagli-Petrucci. In *F. callicarpa*, Miq. they form small widely open pits, the aperture of which is occupied by hairs; in *F. punctata*, Thunb. and *F. falcata*, Thunb., in which the orifice of the pits likewise bears hairs, the pits are provided with three recesses, the middle one of which runs at right angles, while the lateral ones are parallel to the surface of the leaf; in *F. excavata*, King the pits are irregularly lobed, and the lobes open directly to the exterior, no hairs being present. The relatively large stomata, situated above the veins of the leaf in species of *Ficus* and in *Brosimum Alicastrum*, are probably of the nature of water-pores. **Hydathodes**, which are provided with an epithema and are often recognizable with the naked eye as spots or small pits or warts (mentioned in the earlier part of this book, p. 771), besides occurring in many species of *Cecropia, Conocephalus*, and *Ficus*, are found also in *Dammaropsis Kingiana*, Warb. Regarding the structure of these hydathodes, we may add that the number of water-pores, which are invariably of very small size, may be as much as 100 in *Ficus*, although generally less, and is only 10–15 in *Cecropia*. According to Renner, the occurrence of these hydathodes cannot be recommended for use as a specific character, as they may be present or absent in one and the same species.

In most cases the structure of the leaf is bifacial, but in numerous species of *Ficus* belonging to the section *Urostigma* the lowest layer of the **mesophyll** is differentiated as a low palisade, while in the genera *Antiaris, Brosimum, Ficus* Sect. *Urostigma*, and *Pourouma* the entire mesophyll is sometimes found to consist of palisade-tissue, the lower layers being formed by short conjugate palisade-cells. Arm-palisade cells have been observed in the first or second layers of the palisade-tissue or in both these layers in certain species of *Parartocarpus*. A hypha-like differentiation of the spongy tissue is specially characteristic of the species of *Artocarpus* belonging to the section *Jaca* and of certain species of *Ficus* belonging to the section *Urostigma*. In *Parartocarpus excelsus*, Becc., the two lowest layers of the spongy tissue have thick pitted walls and are differentiated like a hypoderm. Spicular fibres, which have a varied course, are recorded by Renner in the following species: *Balanostreblus ilicifolia*, Kurz (only in the veins); *Ficus Bonplandiana*, Miq., *F. crocata*, Mart., *F. doliaria*, Mart., *F. Gardneriana*, Miq., *F. longifolia*, Schott, *F. obscura*, Bl., *F. pisifera*, Wall., *F. tomentella*, Miq.; *Sahagunia Peckoltii*, K. Sch. The great diversity presented by the structure of the **veins** in the Artocarpeae and Conocephaleae cannot be considered here; regarding this point, see Renner, loc. cit.

For the structure of the leaf in the heterophyllous species, cf. Paoli, loc. cit.

Renner demonstrated **laticiferous tubes** (see p. 771) in the leaves of all the

Artocarpeae which he examined. The laticiferous elements present in the leaves are thin-walled sacs, which are from 8–30 μ wide; they are principally found traversing the peripheral portion of the tissue accompanying the veins (sometimes also the medullary tissue of the veins) and in species of many genera[1] also enter into the mesophyll. They belong to the category of laticiferous cells; Mayus's statement as to the occurrence of reticulate anastomoses in *Ficus elastica* is doubtless incorrect. According to Renner the latex of the Artocarpeae is peculiar in containing small spherical masses of caoutchouc side by side with tannin. The same author showed that the contents of the laticiferous elements have a very distinctive character in *Ficus populifolia*, Vahl, inasmuch as they include albuminous substances. Molisch has recently proved that the latex in *Ficus elastica* and in the famous cow-tree (*Brosimum Galactodendron*, Don) is rich in salts of magnesium, which crystallize out from a drop of the latex in the form of round or angular sphaerites. In the Conocephaleae laticiferous cells have been found in the axis of all the genera examined by Renner, as well as in *Musanga* (according to Engler). They occur chiefly in the primary cortex, although occasionally present in the phloem as well, but only rarely (*Pourouma acuminata*, Mart. and *P.* '*mollis*') enter the leaves (lateral veins). Their diameter varies between 25 and 85 μ. Their contents, as far as they are known, never include caoutchouc-bodies, but sometimes contain simple or composite proteid-bodies, which owe their origin to leucoplasts. These proteid-bodies were first discovered by Molisch in *Cecropia peltata*, L. and *Coussapoa Schottii* ('*Brosimum microcarpum*') and are recorded by Renner also in *Cecropia concolor*, Willd., *C. obtusa*, Tréc. and *Pourouma tomentosa*, Mart.

Secretory cells, which have brownish contents of the nature of a gum-resin and which were described for certain species of *Artocarpus* in the earlier part of this book, are rather widely distributed in the sections *Jaca* and *Prainea* of the genus[2]; they appear as inflated spherical or ellipsoidal cells of the spongy tissue, which in these species has a hypha-like differentiation, and in *Artocarpus incisa*, L. f. at least have a suberized wall. In the course of the recent investigations mucilage-canals have been observed among the Conocephaleae in the axis of species of the genera *Cecropia*, *Conocephalus*, *Coussapoa*, *Musanga* and *Myrianthus*, but not in *Pourouma*; they occur in the primary cortex and sometimes in the pith as well. In the leaf, the mucilage-canals of the axis are replaced by rows of mucilage-cells, which are found in the lateral veins of the first order in numbers varying between two and twelve, but only very rarely traverse the smaller veins as well; such rows of mucilage-cells have been demonstrated in *Cecropia*, *Conocephalus*, *Coussapoa*, *Musanga* and *Myrianthus*. In some of the species of the genus *Pourouma* there are mucilage-cells in the lateral veins of the first order. Among the Artocarpeae mucilage-cells are found only in *Olmedia angustifolia*, Poepp.; they are either isolated or united to form groups, and occur in the tissue accompanying the veins. Tannin-idioblasts, situated in the palisade-tissue and differentiated like those of *Ficus rubiginosa*, have been demonstrated by Renner in species of *Antiaris*, *Artocarpus*, *Brosimum*, *Conocephalus*, *Dammaropsis* and *Ficus*[3].

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[1] viz.: *Artocarpus* § *Prainea* and *Pseudojaca*, *Bosqueia*, *Brosimopsis*, *Brosimum*, *Cudrania*, *Ficus*, *Helianthostylis*, *Olmedia*, *Parartocarpus*, *Perebea*, *Sahagunia*, *Scyphosyce*, *Sorocea*, *Sparattosyce*, *Treculia*.

[2] The species in which they have been observed are as follows: *A. anisophyllus*, Miq., *A. Blumei*, Tréc., *A. Chaplasha*, Roxb., *A. communis*, Forst., *A. frutescens*, Renn., *A. hirsutus*, Lam., *A. Kemando*, Miq., *A. lanceaefolius*, Roxb., *A. Limpato*, Miq., *A. Maingayi*, King, *A. mariannensis*, Tréc., *A. nobilis*, Thw., *A. papuanus*, Renn., *A. rigidus*, Bl., *A. scandens*, Renn., *A. Tamaran*, Becc.

[3] The species are: *Antiaris saccidora*, Dalz., *A. toxicaria*, Lesch.; *Artocarpus integrifolius*, L.f., *A. Limpato*, Miq., *A. Polyphema*, Pers.; *Brosimum Aubletii*, Poepp. et Endl., *B. discolor*, Schott, *B. echinocarpum*, Poepp. et Endl.; *Conocephalus lanceolatus*, Tréc., *C. suaveolens*, Bl., *C. tonkinensis*, Renn.; *Dammaropsis Kingiana*, Warb. For the rather numerous species of *Ficus*, which belong to the sections *Urostigma*, *Synoecia*, *Sycidium*, *Eusyce*, and *Sycomorus*, Renner's paper must be consulted.

In most of the Artocarpeae and Conocephaleae clustered crystals constitute the chief form of excretion of **oxalate of lime**, although solitary crystals are also found. In addition to this small, spherical, panduriform or variously shaped crystals or crystalline aggregates of the same salt are occasionally (species of *Artocarpus, Cecropia, Ficus, Parartocarpus*) present in the epidermis of the leaf or in the hypoderm. Oxalate of lime is rarely wanting in the leaf (e.g. in *Helianthostylis Sprucei*, Baill. and *Lanessania turbinata*, Baill.). Large clustered crystals, situated in spherical cells of the palisade-tissue, are not uncommon; the largest idioblasts of this kind are found in *Pourouma*, where they occur in the neighbourhood of the vertically transcurrent veins. A more important systematic feature is afforded by the occurrence of clustered or ordinary solitary crystals in the epidermis of the leaf. The clustered crystals are contained singly in epidermal cells, which are either isolated or united to form groups and occur mainly in the neighbourhood of the veins; in some cases the cells containing the clustered crystals have a round outline and appear as idioblasts (e.g. in certain species of *Ficus*). They have been observed in species of the following genera: *Antiaris, Artocarpus* (§ *Jaca, Prainea* and *Pseudojaca*). *Brosimopsis, Brosimum, Castilloa, Cecropia, Cudrania, Dammaropsis, Ficus* (§ *Urostigma, Palaeomorphe, Sycidium, Covellia, Eusyce*), *Musanga, Olmedia, Perebea, Pourouma, Treculia*. Solitary crystals are found in the epidermis of the leaf in species of *Balanostreblus, Brosimum, Ficus* (§ *Synoecia* and *Urostigma*), and *Sorocea*. In *Ficus aurantiaca*, Griff., *F. callicarpa*, Miq. and *F. punctata*, Thunb., which belong to the section *Synoecia*, the cells containing the crystals combine to form groups; these cells are very small and have strongly thickened inner walls to which the solitary crystals, which fill the entire lumen of the cell, are attached. In *Brosimum Alicastrum*, Sw. the veins are, as it were, paved with the solitary crystals contained in the epidermal cells. In the gelatinized epidermal cells of certain species of *Conocephalus* Renner demonstrated sphaerocrystalline masses of an unknown chemical substance.

We may add the following details regarding the occurrence of **calcification and silicification of the cell-wall** in the Artocarpeae and Conocephaleae. Silicification of the epidermis is no uncommon feature. In the spongy tissue of the older leaves of some species of *Ficus* the walls of the cells bordering on the respiratory cavities are silicified. Silicified pegs, arising from the outer walls of the epidermal cells and penetrating into the cavity of the cell, have been recorded in species of *Antiaris* and *Ficus*, as well as in *Poulsenia aculeata*, Eggers, while tuberous protuberances which are silicified are found in the angles of adjacent cells of the hypoderm in *Ficus diversifolia*, Bl.; lastly, cells filled with siliceous matter are present in the parenchyma accompanying the larger veins in *Ficus aurantiaca*, Griff., *F. brevicuspis*, Miq., *F. clavata*, Wall., *F. obscura*, Bl., *F. pisifera*, Wall., *F. sikkimensis*, Miq., *Parartocarpus Riedelii*, Warb. and *Sparattosyce dioica*, Bur. Regarding silicified trichomes, see below.

Among the Artocarpeae and Conocephaleae Renner observed typical **cystoliths** (i.e. structures provided with a stalk and a variously encrusted body, which shows concentric stratification and in some cases radial striation as well) only in the genera *Conocephalus, Dammaropsis, Ficus, Poulsenia* and *Sparattosyce*. The cystoliths belong exclusively to the integumental tissue and are found both in the upper and lower epidermis; in most cases they are situated in idioblasts, but frequently occur also in ordinary epidermal cells, as well as in hypodermal cells or trichomes. In *Ficus* the lithocysts are invariably concerned in the formation of the surface of the leaf, the only exception being *F. elastica*, in which they belong to the hypoderm. Only a small portion of the wall of the lithocyst participates in the formation of the leaf-surface, and this part of the wall is occasionally provided with a small tip (species of *Dammaropsis, Ficus* and *Poulsenia*) or with a solid attenuated

hair-like peg of greater length (*Sparattosyce*). The shape of the cystoliths is particularly striking in the species of *Conocephalus*, since some of them are two-armed, the arms either spreading out horizontally or diverging obliquely with reference to the axis of the cystolith. In some of the species of *Ficus* the flattened cells containing the cystoliths are accompanied by cells which have a similar shape, but are devoid of cystoliths; the latter are related to the small silicified hairs of *Poulsenia*, &c. discussed below. Among the structures resembling cystoliths we may include the silicified pegs mentioned above as occurring in the epidermis, and the silicified cystotyles, which are recorded by Renner as being suspended from the solid tips of the hairs in *Antiaris*, *Artocarpus papuanus*, Renn. and *Parartocarpus Riedelii*, Warb. In *Cecropia scabrifolia*, A. Richt., lastly, A. Richter figures trichomes, which are completely filled with silicified matter, showing stratification.

The clothing **hairs** in the Artocarpeae and Conocephaleae generally consist of a single cell, and either have a distinct body or appear as short papillose hairs. Now and then a thin transverse wall occurs, so that the hairs become bicellular (*Cudrania*, *Myrianthus*); in other cases several transverse (*Parartocarpus*) or obliquely longitudinal (*Ficus aurantiaca*, Griff.) walls appear in the body of the hair. Uniseriate trichomes with several short basal cells and a long terminal cell, distinguished by the fact that it breaks off at a predetermined point, which is situated at the base of the cell, are developed in *Ficus pilosa*, Reinw. var. *chrysocoma*, King; ordinary uniseriate hairs, which have a brown colour, are rich in tannin and consist of twelve or more cells, are found on the petiolar cushions in *Cecropia*.

The ordinary unicellular clothing hairs frequently serve in a marked manner as a protection against excessive transpiration, e.g. in species of *Cecropia*, *Coussapoa*, *Ficus*, *Musanga*, *Myrianthus* and *Pourouma* (in which they are differentiated as more or less curled and often filiform woolly hairs), in *Artocarpus glaucus*, Bl. and *A. glaucescens*, Tréc. (in which almost all the epidermal cells grow out into clothing hairs), and in certain species of *Coussapoa*, in which the hairs inserted on the veins cover in the areolae (i.e. the spaces between the veins) on the surface of the leaf. It remains specially to mention the following types of trichomes: (*a*) the long clothing hairs, which are found in species of *Castilloa*, *Ficus* and other genera, and are provided with a basal pedestal composed of epidermal cells; (*b*) the trichomes of *Helicostylis Poeppigiana*, Tréc., in which the lageniform base of the hair penetrates deeply into the mesophyll; and (*c*) the bracket-hairs, which, besides occurring in species of *Artocarpus* and *Cecropia*, are found also in species of *Brosimum* and *Lanessania*. The walls of the clothing hairs are often silicified, and when this is the case they frequently have a rough surface due to the presence of knobs of varying shape.

Papillose hairs are found in the first place among the Artocarpeae, where they show varied differentiation. They include: (*a*) the bulbiform trichomes of *Balanostreblus*, *Poulsenia* and *Sahagunia*, which have thick walls and very reduced lumina; (*b*) the silicified trichomes of *Artocarpus frutescens*, Renn., *A. Limpato*, Miq. and *A. scandens*, Renn., the outer wall of which is flat, being protruded only in the middle, while the lateral walls are delicately undulated and pitted; (*c*) the short trichomes of species of *Artocarpus*, belonging to the sections *Jaca* and *Pseudojaca*; the basal portion of these trichomes is enlarged like a spadix and pitted in various ways, while the body of the hair merely appears as a solid and silicified tuberculate knob or as a tip adpressed to one side of the basal portion of the hair. Among the Conocephaleae papillose hairs, which are more or less strongly silicified, occur in *Cecropia*, *Coussapoa*, *Musanga* and *Pourouma*. In *Cecropia latiloba*, Miq., these hairs occur in large numbers in the upper epidermis and have thin walls, while in *C. mexicana*, Hemsl. they have a thick silicified outer wall and are occasionally provided with a thin longitudinal wall. Flat papillose hairs with a minute tip inserted at the centre of the cell are found in other species of *Cecropia*, as well as in *Coussapoa villosa*, Poepp. et Endl. and *Musanga Smithii*. With these hairs we may class the somewhat larger bulbiform trichomes, occurring in certain species of *Cecropia* and *Pourouma*; the latter have a longer tip, and in *Pourouma* even occasionally exhibit delicate longitudinal walls.

The **external glands** of the Artocarpeae and Conocephaleae never form a resinous or oily secretion; they are present in all the genera investigated and, according to Renner, show a varying type of structure. Among the Artocarpeae the stalks of the glands are mostly unicellular; the glands occur isolated on the surface of the leaf and are never arranged in groups. In most cases the glandular head is ellipsoidal or spherical and divided both by longitudinal and transverse walls. Long uniseriate glands, consisting of three or four cells, have been observed among the Artocarpeae only in *Ficus rubiginosa*, Desf. and antler-shaped glands (produced by the outgrowth of the cells of the glandular head into sac-shaped processes) only in *Sparattosyce*. Among the Conocephaleae, *Conocephalus* alone has glands arranged in groups of 2–15; these glands have a unicellular stalk and a head, which consists either of an irregularly shaped mass of from 3–6 cells (*C. ovatus*, Tréc.) or of three or more diverging tubular arms composed of 1–3 cells (*C. suaveolens*, Bl.). In the remaining genera (*Cecropia*, *Coussapoa*, *Musanga*, *Myrianthus*, *Pourouma*) the lower side of the leaf as a general rule bears isolated uniseriate glands, which are long bent structures composed of 4–10 cells, the upper cells being more or less swollen and forming a kind of head. The upper side of the leaf in *Cecropia* bears glands, which have a multicellular stalk and a head, composed of numerous cells and divided both by transverse and longitudinal walls; these glands are either isolated or arranged together in groups comprising from two to four glands. *Musanga*, *Myrianthus* and *Pourouma* have groups of short external glands on the upper side of the leaf, each group consisting of from two to seven glands; the latter are broadly club-shaped and have a stalk, which is made up of short cells and merges gradually into the head, the latter being divided both by transverse and longitudinal walls. In species of *Cecropia* and *Pourouma* transitional forms between the glands found on the upper side and those present on the lower side of the leaf have been demonstrated, while in certain species of *Cecropia* filiform glands have been observed also on the upper side of the leaf.

We may add the following details regarding the structure of the head in the glands of the Artocarpeae. In some cases the heads are merely unicellular or divided by a single longitudinal wall (*Artocarpus* § *Pseudojaca*, *Ficus* § *Urostigma*, *Parartocarpus*, *Scyphosyce*); in other cases they are divided into four quadrants (*Ficus clavata*, Wall., *F. Cunia*, Ham., and species of *Artocarpus* belonging to the section *Prainea*) or have a peltate or flabelliform shape with diverse arrangement of the cells (certain species of *Artocarpus* and *Ficus*).

According to Renner the **pearl-glands** (Müller's bodies), which have already been discussed in the earlier part of this work, are found only in *Cecropia*, and the statement (made on Meyen's authority) as to their occurrence in *Pourouma* should be cancelled. The pearl-glands, which are situated on the petiolar cushions, consist of an epidermis of small cells, which includes an apical stoma, and of a complementary tissue, which is likewise composed of small cells; side by side with the glands of this type the lower surface of the leaf bears pearl-glands, which have an epidermis consisting of large cells but not provided with a stoma, and a complementary tissue, composed of very large cells.

In the main portion of this book no mention was made of the **glandular spots**, which occur on the leaves in many species of *Ficus*, and which in *F. hispida*, L. and *F. leucantotoma*, Poir. are found also on the surface of the branch next to the points of insertion of the petioles; according to Renner they are of the nature of wax-glands and not extrafloral nectaries, as stated by Mirabella. They are provided with a palisade-epithelium, which is without stomata, and are present in species belonging to all the sections. They are found on the lower side of the leaf, where they either lie singly on the midrib and at the base of the lamina or in addition to that occur in pairs in the angles

between the lateral veins of the first order and the principal vein or even in the axils of the more delicate lateral veins; in asymmetrical leaves, it may be noted, the paired glands are found only on that half of the leaf the growth of which has been promoted. In *F. diversifolia*, Bl., in which the median vein is forked, a gland occurs in the angle, formed by the bifurcation. As important from a systematic point of view we may mention that in almost all the species of *Ficus* belonging to the section *Urostigma* (excepting *F. nervosa*, Heyne and *F. pubinervis*, Bl.) there is an unpaired wax-gland at the base of the midrib.

As regards the structure of the **cortex** (p. 775) it is noteworthy that according to Auer the bast-fibres in all the investigated genera of the Moraceae (*Antiaris, Artocarpus, Broussonetia, Cecropia, Cudrania, Ficus, Maclura, Morus, Olmedia, Streblus*) agree in the fact that the outer thickening-layers appear as an envelope around the inner layers.

In *Artocarpus incisa*, L.f. and *A. integrifolia*, L.f. the stalks of the fruiting-axes show polystelic structure.

4. URTICEAE (pp. 775–778

To the Review of the Anatomical Features we may add that bundles of raphides and styloids occur in *Laportea*, secretory organs resembling laticiferous tubes in *Urera baccifera*, Gaud. and mucilage-canals also in *Laportea*.

For the **structure of the leaf** in *Laportea*, see Quanjer, loc. cit. In *Laportea* the stomata are likewise provided with three subsidiary cells arranged according to the Cruciferous type. According to Nestler hydathodes, similar to those found in *Pilea serpyllifolia* and appearing as slight prominences, are scattered over the entire upper surface of the leaf in *Böhmeria tenacissima*, Gaud. (= *B. nivea*, Gaud.). A single layer of hypoderm is present on the upper side of the leaf in *Laportea stimulans*, Miq., but not in *L. sinuata*, Bl., which is mentioned as a synonym of *L. stimulans* in the Kew Index.

To the section dealing with the **cystoliths** we may add that in *Laportea* they are situated in the epidermis of the leaf and have a distinct stalk, while the cells containing them in some cases (*L. sinuata*, Bl.) are provided with a papillose tip. In *L. peltata*, Gaud. deposits of carbonate of lime have been observed on the surface of the leaf, and in *L. sinuata*, Bl., they are found in the mesophyll as well. The new record of the occurrence of raphides and styloids in *Laportea* is contained in Quanjer's paper and is correct.

The glandular **hairs** in *Laportea* are provided with a short stalk and a head divided by vertical walls.

According to Guérin the **secretory organs** of *Urera baccifera* above mentioned resemble laticiferous tubes; they occur in the periphery of the pith, the inner portion of the primary cortex and the secondary bast of the stem, in the cortex of the root and in the neighbourhood of the vascular bundles in the veins of the leaf. The elements found in the pith branch after the manner of laticiferous cells. On the basis of my own observation I may add that the xylem-mass in the stem of *U. baccifera* contains tangential bands of unlignified parenchymatous tissue, which show a concentric arrangement.

Mucilage-canals have been observed in the larger veins of the leaf of *Laportea stimulans*, Miq. var. *costata*, while in the veins of the leaf of *L. sinuata*, Bl. Quanjer merely found an intercellular canal without any secretion.

Literature: Karsten, *Cecropia peltata*, Nova Acta Leopold.-Carol., 1858; and in Ges. Beitr., i, 1865, pp. 241–52.—Trécul, Gomme et tannin dans le *Conocephalus naucleiflorus*, Ann. sc. nat., sér. 5, t. ix, 1868, pp. 274–81.—Faivre, Latex du Murier blanc, Ann. sc. nat., sér. 5, t. x, 1869, pp. 97–122.—Costantin, Tiges aér. et sout., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 85 et seq.—[Möller, Nesselfaser, Deutsch. allg. polytechn. Zeit., 1883, n. 34, 35.]—Keller, Luftwurzeln, Diss., Heidelberg, 1889, pp. 26–30.—Lothelier, Épines, Thèse, Paris, 1893, pp. 16, 17 and pl. i.—[Bigelow, Glands in the Hop tree, Proceed. Iowa Acad. of Sc., ii, 1895, pp. 138–40, 1 pl.]—Mirabella, Nettarii

estrannz. nelle varie specie di *Ficus*, Nuovo Giorn. bot. Ital., n. s., ii, 1895, pp. 340–7 and Tab. x.—Tschirch, Herba *Cannabis indica*, in Anat. Atlas, i, 1895, Tab. xv and p. 55 et seq.—Went, Haft- u. Nahrwurz., Ann. Jardin Buitenzorg, xii, 1895, pp. 48–54.—[Briosi e Tognini, Anat. della Canapa, Parte ii, Atti Ist. bot. di Pavia, Ser. 2, iv, 1896, p. 175 et seq., 26 tab.; abstr. in Beih. z. Bot. Centralbl., viii, 1898–9, pp. 27–9, and in Just, 1897, i, p. 523.]—Büttner, Cortex Mururé (*Urostigma cystopodum*, Miq.), Diss., Erlangen, 1896, 31 pp.—Jönsson, Anat. Bau d. Blattes, Acta Univers. Lund., xxxii, 2, 1896 (*Pellionia*).—[Baccarini e Buscemi, Nettarii foliari della *Olmediella Cesatiana*, Baill., Bull. Accad. Gioenia Catania, Fasc. lvi, 1898, pp. 10–13; abstr. in Just, 1898, ii, p. 386.]—Engler, Moraceae, in Monogr. afrikan. Pfl.-Fam. u. -Gatt., 1898, pp. 8–10 and 38, 39.—Mirabella, Laticiferi delle radici aëree di *Ficus*, Contribuz. biolog. veget. Ist. bot. Palermo, ii, 1898, pp. 131–6.—Grélot, Caoutchoucs et Guttapercha, Thèse, Paris, 1899, p. 133 et seq.—Haberlandt, Neues Organ bei *Conocephalus ovatus*, Festschrift f. Schwendener, 1899, pp. 104–19.—Houlbert, Phylogénie des Ulmacées, Revue gén. de Bot., 1899, pp. 106–19 and pl. 2, 3.—Nestler, Wasserausscheidung an den Blättern von *Böhmeria*-Arten, Sitz.-Ber. Wiener Akad., cviii, Abt. i, 1899, pp. 706–8 and Tab.—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 20–3.—Ursprung, Anat. u. Jahresringbild. trop. Holzarten, Diss., Basel, 1900, pp. 5–8 (*Artocarpus integrifolia*, L. f.).—Bargagli-Petrucci, Cavità stomatifere nel genere *Ficus*, Nuovo Giorn. bot. Ital., n. s., viii, 1901, pp. 492–8.—Molisch, Milchsaft u. Schleimsaft, 1901, pp. 6, 21, 49 and 55.—Petersen, Vedanatomi, 1901, pp. 38–40 (*Ulmus*).—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 84, 85.—A. Richter, Luftwurz., Bibl. bot., Heft 54, 1901, p. 44 and Tab. xiv.—[Baar, Milchröhren, Sitz.-Ber. 'Lotos' in Prague, 1902, n. 4, 5; abstr. in Bot. Centralbl., xcii, p. 406.]—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 290 et seq. (*Artocarpus*, *Sloetia*); and *Conocephalus*, Nuovo Giorn. bot. Ital., ix. 1902, p. 213.—Bouygues, Pétiole, Thèse, Paris, 1902, p. 15.—Cas. de Candolle, Hypoascidies de *Ficus*, Bull. Herbier Boissier, sér. 2, t. ii, 1902, pp. 753–62 and 2 pl.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 39, 40 (*Gesnouinia*).—Copeland, Haberlandt's new organ of *Conocephalus*, Bot. Gazette, 1902, pp. 300–8.—Auer, Bastfasern d. Moraceen, Österreich. bot. Zeitschr., 1903, pp. 353–6.—Quanjer, Anat. bouw, &c., Natuurkund. Verhandel. Haarlem, iii, 5, 1903 (*Artocarpus*, *Laportea*).—Solereder, *Artocarpus laciniata*, Hort., Bull. Herbier Boissier, sér. 2, t. iii, 1903, pp. 518–20.—Tuzson, Spiralige Struktur d. Zellw. in den Markstr., Ber. deutsch. bot. Gesellsch., 1903, p. 276.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 124–8.—Kniep, Bedeut. d. Milchsaft., Flora, 1904, pp. 168, 169.—Paoli, Eterofillia, Nuovo Giorn. bot. Ital., xi, 1904, pp. 188–204 and Tab. i.—Solereder, Zwei Berichtigungen, Bull. Herbier Boissier, sér. 2, t. iv, 1904, pp. 318–23.—Areschoug, Trop. växt. bladbyggn., Sv. Vet. Akad. Handl., 39, n. 2, 1905, pp. 9–11 and pp. 113–15, Tab. ix, x and xv (*Artocarpus*) and pp. 112, 113, Tab. xv, xvi (*Antiaris*).—Frommel, Plantas chil. text., 1905, p. 31.—Guérin, Laticifères de l'*Urera baccifera*, Bull. Soc. bot. de France, 1905, p. 406 et seq.—Mayus, Milchr., Beih. z. Bot. Centralbl., xviii, 1. Abt., 1905, pp. 275, 276.—Sarton, Anat. d. pl. affines, Ann. sc. nat., sér. 9, t. ii, 1905, pp. 60–2 (*Parietaria*).—Dauphiné, Rhizomes, Ann. sc. nat., sér. 9, t. iii, 1906, p. 363 et seq.—Perrot, Gilbert, Carnot et Choay, Rech. sur les *Cecropia*, in Perrot, Travaux, iii, 1906, 38 pp.; also Bull. d. sc. pharmacol., xi, 1905.—Piccioli, Gelsolino, sep. copy, 1906, 13 pp.—Piccioli, Legnami, Bull. Siena, 1906, pp. 135, 170, 174 and 175.—Renner, Anat. u. Syst. d. Artocarpeen u. Conocephaleen, insbes. d. Gatt. *Ficus*, Diss., Munich, 1906; sep. copy from Engler, Bot. Jahrb., xxxix, pp. 319–448.—Renner, Wachsdrüsen auf d. Bl. u. Zweigen von *Ficus*, Flora, 1907, pp. 24–37.—Boorsma, Aloëholz, Bull. du départ. de l'agricult. aux Indes néerl., n. vii, 1907, p. 32 (*Celtis*).—Holtermann, Einfluss d. Klimas, 1907, pp. 17, 106, 135 and 136.—[Schorn Schleimz. bei einigen Urticaceen u. Schleimcystolithen bei *Girardinia palmata*, Anzeiger Wiener Akad., Math.-naturw. Kl., 1907, p. 65; and in Sitz.-Ber. Wiener Akad., cxvi, Abt. 1, 1907, pp. 393–410, 2 Tab.]

Appendix: Tribe VII. THELYGONEAE (p. 779).

In *Thelygonum* the upper epidermis of the leaf is characterized by the formation of papillae.

Literature: Gutenberg, Lichtsinnesorg., Ber. deutsch. bot. Gesellsch., 1905, pp. 269, 270 and Tab. x, xi.

PLATANACEAE (pp. 779–781).

According to Bouygues, the vascular bundles of the **petiole** are what he calls 'pseudo-faisceaux rayonnés.' In the mature condition they show an annular arrangement, although they do not arise from a single procambial strand; in correspondence with this their conjunctive tissue resembles the ground tissue.

Literature: Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 81, 82.—Bouygues, Cert. formes vasc. anorm. du pétiole, Act. Soc. Linn. Bordeaux, lvii, 1902, pp. 91, 92.—Tuzson, Spiralige Struktur d. Zellw. in den Markstr., Ber. deutsch. bot. Gesellsch., 1903, p. 276.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 141.—Piccioli, Legnami, Bull. Siena, 1906, p. 125.

JUGLANDEAE (pp. 783-785).

Literature: Kassner, Mark einiger Holzpfl., Diss., Basel, 1884, pp. 11-15 and Tab. i.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 55-7.—Col, Faisceaux. Ann. sc. nat., ser. 8, t. xx, 1904, p. 146.—Piccioli, Legnami. Bull. Siena, 1906, pp. 131 and 171.

MYRICACEAE (pp. 785, 786).

The Anatomical Characters of the Order, which were enumerated in the earlier part of this book, are confirmed by the results of Chevalier's recent researches. It only remains to point out that in addition to the peltate external glands one finds stalked capitate glands, which are either uniseriate or unicellular, and that uniseriate clothing hairs occur side by side with the unicellular ones.

The Structure of the Leaf is now adequately known as a result of Chevalier's investigations. The leaves are almost always bifacial in structure, the palisade-tissue consisting of one or two or sometimes of several layers. The **stomata** are confined to the lower side of the leaf, and are either raised above the level of the epidermis (e.g. in *Myrica Faya*, Ait.) or covered in by the neighbouring cells (as in the sections *Comptonia* and *Gale*). They develop according to the Ranunculaceous type and have 5-10 neighbouring cells; in *Myrica cordifolia*, L., they are restricted to deep pits in the surface of the leaf, while in *M. Gale*, L., they are distinguished by the papillose character of the neighbouring cells. The **epidermal cells** are for the most part small and have straight or undulated lateral walls; the cuticle is commonly granular, more rarely striated. Papillose differentiation of the lower epidermal cells, like that observed in *M. Gale*, appears to occur rather frequently. *M. javanica*, Bl. is alone characterized by the possession of a **hypoderm**, which is situated on the upper side of the leaf and consists of two layers. The peltate **glands** mentioned in the earlier part of this book are present in almost all the species; their shield, as we may notice in passing, may be divided both by tangential and radial walls and the component cells may eventually even show an irregular arrangement. Side by side with these glands other types of glandular hairs occur. In *M. Gale*, L., *M. asplenifolia*, L. and *M. esculenta*, Buch.-Ham. isolated epidermal cells of the ordinary kind occasionally function as glands; they become filled with oil, and their walls remain thin, while the outer walls become slightly arched outwards. In species of the sections *Comptonia* and *Gale* (e.g. *Myrica Gale*) one also finds uniseriate external glands, which are composed of three or four cells; of these either the terminal cell or one of the middle cells secretes oil. It is no great step from these forms to the stalked external glands, which, for instance, are likewise found in *M. asplenifolia* and *M. esculenta* and have heads composed of a small number of cells. It remains to mention those types of peltate glands, in which the shield is provided with a jagged margin (e.g. in *M. pennsylvanica*, Lois.-Desl.). Unicellular sclerotic clothing hairs, which have either a smooth or a verrucose surface, are found in varying abundance in all the species. In *M. Zeyheri*, C.DC. and *M. asplenifolia* these trichomes occasionally occur in pairs, while in *M. pennsylvanica* and *M. quercifolia*, L., their basal portion is surrounded by several rows of small subsidiary cells; in *M. asplenifolia* small peg-shaped outgrowths, which penetrate in between the neighbouring epidermal cells, are often developed on the base of the hair. In the hairs of *M. esculenta*, Buch.-Ham. var. *longifolia* (Teysm. et Binn.) Chevalier figures a few relatively thin transverse walls.

Three vascular bundles enter the **petiole**; in their further course these bundles approach one another and ultimately fuse to form an arc of wood and bast. In rare cases the lateral bundles undergo subdivision, so that five

vascular bundles are to be found at certain points (e.g. occasionally in *M. Nagi*, Thunb.).

As regards the structure of the **cortex** we may add the following details. The primary medullary rays between the groups of bast broaden out towards the exterior in the shape of a wedge. There are no sclerenchymatous elements in the secondary bast in *M. Gale*, in contrast to *M. asplenifolia* (where they are generally isolated) and other species (where they form groups). Secretory cells (' cellules mortes de lignine gommeuse ' according to Chevalier ; ' Zellen mit rotgefärbtem Milchsaft ' according to Beringer) occasionally (e.g. in *M. asplenifolia*) occur in the cortex. The statements in the literature as to the occurrence of laticiferous tubes or laticiferous vessels (see Hooper and Dymock) have as little foundation as the recorded presence of resin-canals [1], discussed in the earlier part of this book.

Literature: [Dymock, Indian Drugs, Pharm. Journ. and Transact., 1880, p. 581 et seq.; abstr. in Bot. Centralbl., 1880, iii, p. 977.]—[Hooper, *Myrica Nagi*, Americ. Journ. Pharm., 1894, p. 209; abstr. in Just, 1894, ii, p. 410.]—[Beringer, *Myrica*, Americ. Journ. Pharm., 1894, p. 220; abstr. in Just, 1894, ii. p. 401.]—[Planchon et Collin, Drogues simples, Paris, 1895 (*Myrica cerifera*).]—Chevalier, Appareil végétatif des Myric., Comptes rendus Assoc. franç. pour l'avancement des sc., Nantes, 1898, i, publ. 1899, p. 164, and ii, 1899, pp. 457–66.—Kearny, in Contribut. U. S. Nat. Herb., v, n. 5, 1900, p. 294.—Chevalier, Monographie des Myricacées, Thèse, Paris, 1901, 237 pp., 8 pl., 1 carte; also in Mém. Soc. sc. de Cherbourg, xxxii.—[Krembs and Denniston, Structure of the stem of *Myrica Gale* and *M. cerifera*, Proceed. Americ. Pharm. Assoc., 1901, pp. 414–23.]—Petersen, Vedanatomi, 1901, pp. 37, 38.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 78, 79.—Clauditz, Blattanat. canar. Gew., Diss., Basel, 1902, pp. 44–6.

CASUARINEAE (pp. 786–790).

For the detailed structure of the **stomatal apparatus** in *Casuarina*, see Porsch, ll. cc. According to this author a particularly noteworthy feature from the phylogenetic standpoint, considered in relation to the indications of affinity between the Casuarineae and the Gymnosperms, lies in the intercalation of cutine-lamellae in the cellulose-membrane of the dorsal and ventral walls of the guard-cells, which are rather deeply sunk. These lamellae completely coincide with the ' xylem-lamellae ' of Gymnospermous stomata both in their shape and in the extent of their development.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 50.—[Morini, Anat. della radice delle Casuarin., Mem. Accad. Bologna, Ser. 5, vol. 6, pp. 201–24, 2 tab.; abstr. in Just, 1897, i, p. 507.]—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 288.—Porsch, Spaltöffnungsapparat von *Casuarina* u. seine phyletische Bedeut., Österreich. bot. Zeitschr., 1904, n. 1 et seq.; sep. copy, 21 pp. and Tab. iii.—[Maiden, *Casuarina inophloia*, Proc. Linn. Soc. New S. Wales, 1905, p. iii.]—Porsch, Der Spaltöffnungsapparat im Lichte der Phylogenie, Jena, 1905, p. 17 et seq.

CUPULIFERAE (pp. 791–797).

2. Structure of the Leaf. The following supplementary facts refer mainly to the structure of the leaf in *Quercus* (excl. *Pasania*), which has recently been examined in detail especially by Schott, Küster and Brenner. Isolateral structure, like that found in *Q. Ilex*, occurs in the leaves of many species, e.g.: *Q. agrifolia*, Née, *Q. alnifolia*, Poech, *Q. calliprinos*, Webb, *Q. chrysolepis*, Liebm., *Q. cinerea*, Michx., *Q. coccifera*, L., *Q. crassipes*, Humb. et Bonpl., *Q. incana*, Roxb., *Q. macrolepis*, Kotschy, *Q. persica*, Jaub. et Spach, *Q. Vallonea*, Kotschy, and *Q. xalapensis*, Humb. et Bonpl. (according to Schott). **Hypoderm** is present in a few species of *Quercus* (e.g. in *Q. xalapensis* according to Schott, in *Q. densiflora*, *Q. glabra* and *Q. pachyphylla* according to Küster, and in *Q. virginiana*, L. according to Kearny). A tendency to form papillae on the lower **epidermis** is recorded by Küster in *Q. Ballota*,

[1] According to Chevalier the plant, which was examined by Höhnel under the name of *Myrica sapida* and was found to be provided with resin-canals, is probably *Podocarpus Nagi*.

Q. cuspidata, and *Q. glabra*, by Schott in *Q. chrysophylla*, and by **Köhne also** in *Alnus incana*, Willd. and *A. rubra*, Bong. In all the species of *Quercus* that have been examined, the **stomata** are confined to the lower surface of the leaf. For the detailed structure of the stomata in *Q. Ilex*, see Guttenberg, loc. cit.; a particularly noteworthy feature is that the guard-cells develop peculiar longitudinal cuticular folds on the upper portion of the ventral walls, which surround the front cavity; in a transverse section these folds appear as small projecting horn-like outgrowths, lying opposite to one another. Less strongly developed ridges of the same type have been observed also in *Q. Suber*, L. In the majority of the species of *Quercus* three arcs of wood and bast are found between the base and the middle of the midrib of the leaf, and the same is the case in the **petiole**; the upper arc is inversely orientated (with the phloem on the upper side), while the middle and lower arcs are normally orientated. The middle one arises from the upper one by the inrolling of its ends (i.e. by a process of twisting through an angle of 180°); for the distribution of this median arc of wood and bast (which was first observed by Frank) in the genus *Quercus*, see C. de Candolle and Schott, ll. cc. For details as to the structure of the margin and teeth of the leaf in the species of *Quercus*, see likewise Schott.

To the previous discussion of the clothing **hairs** (p. 792) we may add the following details. Simple unicellular clothing hairs with walls of varying thickness also occur in *Quercus*, although not very commonly (e.g. in *Q. annulata*, *Q. dentata*, Thunb., *Q. glandulifera*, Bl., *Q. hungarica*, *Q. mongolica*, Fisch., *Q. robur*, L., *Q. sessiliflora*, &c.). On the other hand stellate and tufted hairs are widely distributed in the genus *Quercus*, the number of ray-cells occasionally being small (2–4) and large in one and the same species. The following types require special mention: (*a*) in the stellate hairs, which cover in the stomata on the lower surface of the leaf in *Q. leucocarpa*, Hook. f. et Th. and *Q. Henryi*, Seem., the 3–5 rays show unilateral development, and the hairs, as seen from the surface, resemble a hand with outspread fingers (according to Brenner); (*b*) the stellate hairs of *Q. crassipes*, Humb. et Bonpl., *Q. fulva*, Liebm., *Q. imbricaria*, Michx. and *Q. nitens*, Mart. et Gal., in which the lower parts of the ray-cells are fused to form a stalk to the hair (according to Schott); (*c*) the tufted hairs of *Q. Brantii*, Lindl., which are composed of a particularly large number of cells (forming as many as 20 rays), and in which the ray-cells are arranged approximately in two tiers (according to Schott); (*d*) lastly hairs, which resemble stellate trichomes or small scales and have thin cell-walls; these are described by Brenner, who figures them in *Q.* '*Sieboldii*' and records them also in *Q. cuspidata*, Thunb., *Q. Junghuhnii*, Miq., *Q. lanceaefolia*, Roxb. and *Q. sclerophylla*, Lindl. et Paxt. According to Schott true peltate hairs occur in *Q. nigra*, L., which is not included in the section *Pasania*, but in the section *Erythrobalanus*; the shield has a jagged margin, and the 8–14 ray-cells of which it is composed meet in the centre. We may add that according to Küster brown stellate hairs are found on the *Lenticularis*-galls of *Q. pedunculata*, and two-armed hairs on the *Numismatis*-galls of the same species; the type of hair first named is not normally present in *Q. pedunculata*, while two-armed hairs have not as yet been observed as a normal feature in any species of *Quercus*. The two types of glandular hairs, previously described by me in *Q. Farnetto*, occur also in other species of *Quercus*. Thus according to Küster uniseriate glandular hairs (Fig. 187, *I*) are found also in *Q. alba*, *Q. aquatica*, *Q. glaucoides*, *Q. magnoliaefolia*, *Q. nigra*, *Q. oblongifolia*, *Q. reticulata*, *Q. Sartorii*, *Q. undulata*, and according to Schott in *Q. alnifolia*, Poech and *Q. imbricaria*, Michx.; according to Küster capitate glandular hairs are present in *Q. pedunculata*, *Q. ilicifolia*, *Q. lyrata*, *Q. macrocarpa*, &c. Brenner (loc. cit., p. 154) also records glandular hairs, which probably function as

hydathodes, in *Q. reflexa*, King and other species, but the details of their structure are not recognizable in his figure (30 a, a).

3. Structure of the Axis. For the strongly developed cork-wings found on the axes of *Q. macrocarpa*, Michx., see Gregory, loc. cit. Regarding a peculiar spiral structure in the medullary rays, see Tuzson, loc. cit.; this feature is only noticed at points at which the xylem-mass is ruptured and is particularly well shown by *Fagus silvatica*, but also by *Alnus incana*, *Betula verrucosa*, *Carpinus Betulus*, *Ostrya carpinifolia*, *Quercus Cerris* and *Q. sessiliflora*.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 52 et seq.—Kügler, Kork von *Quercus suber*, Archiv d. Pharm., 1884, pp. 217–30.—Gregory, Cork-wings, Bot. Gazette, 1888, pp. 249, 250.—Hartig, Eichenholz, Sitz.-Ber. Münch. Akad., 1894, p. 385 et seq. and elsewhere.—[Lamey, Chêne liège, Paris, 1894.]—Köhne, Papillen u. obers. Spaltoffn., Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 53.—Kearny, in Contribut. U. S. Nat. Herb., v, n. 5, 1900, p. 294.—Küster, Bemerk. über die Anat. d. Eichen, Bot. Centralbl., 1900, iii, pp. 177–85.—Eug. Ant. Müller, Korkeiche, Abh. k. k. geogr. Gesellsch. Wien, ii. 1900.—Schott, Anat. Bau d. Blattes d. Gatt. *Quercus*, Diss., Heidelberg, 1900, 53 pp., 3 Tab.—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 17–20.—Petersen, Vedanatomi, 1901, pp. 28 37.—Pitard, Péricycle, Thèse. 1901, pp. 62–4.—Bargagli-Petrucci, Legnami, Malpighia, 1902, p. 289 (*Quercus*).—W. Brenner, Klima u. Blatt bei *Quercus*, Flora, 1902, pp. 114–60.—[Piccioli, Monografia del Castagno, Firenze, 1902.]—Simon, Holzkörper sommer- u. wintergrüner Gew., Ber. deutsch. bot. Gesellsch., 1902, pp. 242–4 and Tab. xi.—Tuzson, Spiralige Struktur d. Zellwand in den Markstr. des Rotbuchenholzes, Ber. deutsch. bot. Gesellsch., 1903, pp. 276–9.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 146–9.—H. Winkler, Betulaceae, in Pflanzenreich, Heft 19, 1904, pp. 3, 4.—Süssenguth, Behaarungsverh. d. Würzb. Muschelkalkpfl., Diss., Würzburg, 1904, p. 51.—Haberlandt, Lichtsinnesorg., 1905, p. 97 and Tab. i.—Piccioli, Querci Italiane, Firenze, 1906, 60 pp.—Piccioli, Legnami, Bull. Siena, 1906, pp. 133, 137, 139, 143, 168, 169, 176.—Guttenberg, Immergr. Laubbl. d. Mediterranflora, in Engler, Bot. Jahrb., xxxviii, 1907, pp. 417–19 (*Quercus Ilex*).— [For further literature, see p. 1170.]

SALICINEAE (pp. 797–799).

The following further points of distinction between the two genera of this Order may be added: *Populus* alone has bundles of sclerenchymatous fibres in the medullary sheath, and invariably has stone-cells in the cortex, while stone-cells are never present in the cortex in *Salix*; the cork in *Salix* always contains cells with rather strongly thickened outer tangential walls, whereas such cells do not occur in the cork in *Populus*. As regards the mode of origin of the cork, which in the earlier part of this book was mentioned as a means of distinguishing the two genera, recent investigations have confirmed the statement that epidermal development of the cork is characteristic of *Salix*; in *Populus* the cork generally arises in a subepidermal position and in *P. Fremontii* alone (according to Perredès) in the third layer of the primary cortex.

The following additions on the structure of the leaf deal principally with *Salix* and are based on Camus's observations. The type of stoma, previously described in *Salix*, is present throughout the genus; the **stomata** in *Salix* are always found on both sides of the leaf. Gelatinized **epidermal cells** have been recorded also in *S. babylonica*, *S. caesia*, *S. glabra*, *S. glauca*, *S. hastata*, *S. helvetica*, *S. Lapponum*, *S. pentandra*, *S. phylicifolia*, *S. pyrenaica*, *S. repens*, *S. reticulata* and *S. retusa*. In all probability, however, they are even more widely distributed, for the 1–3 tangential walls described by Camus are probably in all cases (this is certainly so at least in *S. nigricans*, as I have found by a reinvestigation of this species) merely the cellulose-lamellae of gelatinized cell-walls. Wax (in the form of small rods) is excreted on the surface of the leaf in many species of *Salix*. The **mesophyll** is differentiated after the manner of a hypoderm (just as in *S. alba*) also in *S. babylonica*. In alcohol-material of the leaves of *S. cinerea*, *S. daphnoides* and other species Camus observed sphaerocrystalline excretions (cf. also the abstract of Dobrowlianskij's earlier paper in Just, 1893, I, p. 560 et seq.). In connexion with the glandular leaf-teeth and the glandular spots on the bud-scales, mentioned

on p. 798 as occurring in *Populus*, we may point out that in many species of this genus extrafloral **nectaries** are found on the leaves formed in **spring**, or even on all the leaves; the structure of these nectaries, which are situated at the apex of the petiole, is similar to that of the leaf-teeth (Trelease).

To the section dealing with the structure of the **wood** we may add that in *Salix aurita* and *S. cinerea* (but not in *S. Caprea*) portions of the wood project like ridges into the bast; this feature occurs also in other species of *Salix*, but is less distinct (Camus).

In turning our attention to the structure of the **cortex** we may once more refer to the above-mentioned features distinguishing *Populus* and *Salix* (presence or absence of stone-cells and structure of the periderm); they were determined by Soštarič and Perredès. According to Camus the **pericycle** in *Salix* usually contains a ring of fibres, which subsequently becomes burst open, while in other cases isolated groups of fibres are present from the first; in the creeping and procumbent axes of *S. herbacea* and *S. polaris* and in those branches of other species, which show the same habit, there are no pericyclic fibres. The groups of fibres in the secondary bast vary in abundance in *Salix*; in *S. reticulata* no secondary hard bast was found, even in thick axes.

Regarding the **pith** the following details may be added on Soštarič's authority. In most of the species of *Populus* the inner cells of the pith are partly lignified and partly unlignified; in *P. euphratica* alone all the cells have thick lignified walls. As regards the genus *Salix* the medullary cells are lignified in the shrubby willows, while in the dwarf and glacial willows only isolated cells of the pith are lignified, or (*S. retusa*, L.) lignified cells are completely absent. In the case of *Populus euphratica* the groups of sclerenchymatous fibres, characteristic of *Populus* (see above), are present not only at the margin of the pith, but are scattered throughout its entire mass. According to Camus carbonate of lime is deposited also in the pith of *S. triandra*.

Literature: Höhnel, Gerberinden, Berlin, 1880, p. 87 et seq.—[Trelease, Nectar-glands of *Populus*, Bot. Gazette, 1881, pp. 284–90.]—[Theorin, Om bladstendsglanderna hos en del Salices, Stockholm, 1882.]—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.—Soštarič, Bau des Stammes d. Salicin., Sitz.-Ber. Wiener Akad., cvii, Abt. i, 1898, pp. 1210–19; and Österreich. bot. Zeitschr., 1899, p. 117.—Köhne, Papillen u. oberseit. Spaltöffn., Mitteil. deutsch dendrolog. Gesellsch., 1899, p. 52.—Paulesco, Struct. anat. des hybrides, Thèse, Genève, 1900, p. 90 (*Salix*).—Tunmann, Sekretdrüsen, Diss., Bern, 1900, pp. 14–17.—Petersen, Vedanatomi, 1901, pp. 24–7.—Pitard, Péricycle, Thèse, Bordeaux, 1901, pp. 94, 95.—Perredès, Comp. anat. of the barks of Salicin., Pharm. Journ., 1903; sep. copy from Wellcome Chem. Research Labor., n. 39, 34 pp., 6 pl.—Col, Faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, p. 149.—Camus, Classificat. des Saules d'Europe et monogr. des Saules de France, Journ. de Bot., 1904, p. 175 et seq., and 1905, p. [1] et seq.; especially 1904, pp. 184–213 with anatomical diagnoses of the individual species).—[Camus, Atlas de la monogr. des Saules, Paris, 1904, with eight anatomical plates.]—[Penhallow, Syst. Study of the Salic., Americ. Naturalist, xxxix, 1905, pp. 509–35 and 797–838; abstr. in Just, 1905, ii, p. 13 et seq.]—Piccioli, Legnami, Bull. Siena, 1906, p. 143.—[Gaertner, Vergl. Blattanat. z. Syst. d. Gatt. *Salix*, Diss., Göttingen, 1907, 59 pp.]

EMPETRACEAE (pp. 800, 801).

Literature:—Boergesen, Arkt. pl. bladbygn., Bot. Tidsskrift, xix, 1895, p. 219 et seq.—Petersen, Vedanatomi, 1901, pp. 46, 47.—Theorin, Växttrichom., Arkiv for Bot., i, 1903, p. 161.

CERATOPHYLLEAE (pp. 801–803).

The oily contents found in young stages in the shaggy structures consist of myriophyllin; cells containing myriophyllin, moreover, are also found distributed through the tissues of the plant (Strasburger).

Literature: Weinrowsky, Scheitelöffn. bei Wasserpfl., Diss., Berlin, 1898, p. 22 (also in Fünfstück, Beitr., iii).—Roedler, Assimilator. Gewebesyst., Diss., Freiburg i. d. Schw., 1898–9, p. 37.—Strasburger, *Ceratophyllum demersum*, in Pringsheim Jahrb., xxxvii, 1902, p. 500 et seq. and Tab. x, xi.

CONCLUDING REMARKS

THE following pages are devoted to a review of those anatomical characters which have proved to be of taxonomic value, with reference to their occurrence[1] in particular Orders, genera, or species. In the course of our survey the varying systematic value, which, as experience has shown, attaches to the individual anatomical characters, will become evident. These concluding remarks may therefore serve both as an aid in the determination of a plant by means of its anatomical characters, and (in conjunction with the Introduction on p. 1 et seq.) as a guide to the anatomical method.

In this review, however, it is not my intention to propound any definite doctrine, nor to forestall in any way the results of free and independent research. The facts and views presented in these pages are merely relative to the present state of our knowledge and refer only to the plant-material hitherto investigated, the precise nature of which is mentioned under the individual Orders in the main part of this book; as the result of further investigations these statements will often enough require amplification or restriction. Let the guiding principle in systematic-anatomical investigations be invariably to take all the anatomical features into consideration and to test their systematic value in each individual case.

The anatomical characters are discussed in the following seven chapters:— I. Structure of the lamina of the leaf; II. Structure of the petiole; III. Secretory and excretory receptacles; IV. Hairy covering; V. Normal structure of the axis; VI. Anomalous structure of the axis; VII. Structure of the root.

1. STRUCTURE OF THE LAMINA OF THE LEAF[2].

§ 1. SIMPLE EPIDERMIS. The epidermis of the leaf exhibits a large number of structural variations, which for the most part constitute biological characters and are generally only of value for specific diagnosis.

These variations are primarily connected with the **shape of the cells in surface-view.** As a rule the epidermal cells, when seen from the surface, are approximately isodiametric, the lateral walls being either straight or undulated. It is chiefly the extreme types of structure shown by the lateral walls on any one surface of the leaf that are of value for taxonomic purposes, and more especially for specific diagnosis, whilst variation of these characters within narrow limits (e.g. straight and slightly curved lateral walls, or lateral walls curved to a varying extent) occurs frequently enough in one and the same species. Epidermal cells with curved lateral walls, moreover, are found especially in species growing in damp habitats, while epidermal cells with

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[1] In reviewing the distribution of those anatomical features which are of frequent occurrence, as a rule only Orders and anomalous genera are cited.

[2] As in the descriptions of the individual Orders (under 'Structure of the Leaf') certain anatomical characters of the axis (such as spicular cells, &c.), which correspond to analogous features in the leaf, are likewise taken into consideration.

For the anatomical structure of subterranean leaves, we may refer to the paper by Thomas (Anat. comp. et exp. des feuilles sout., Thèse, Paris, 1900, 106 pp.; see also Revue gén. de Bot., 1900, p. 394 et seq.).

straight lateral walls are common in species occupying a dry habitat; the former type of cell in general occurs more frequently on the lower than on the upper side of the leaf

The following **special forms of epidermal cells** require mention. In certain species belonging to a large number of different Orders (e.g. Ranunculaceae, Papilionaceae, Laurineae, Euphorbiaceae, &c.) one finds epidermal cells with their lateral walls more or less bent in a zigzag fashion, while the apices of the angles exhibit ridge-like projections, the ends of which are swollen in a nodose manner or in the shape of a T, much as in the petals of many plants. A local separation of the lateral walls has been observed in species of *Ranunculus*. In narrow leaves (Caryophylleae, Papilionaceae, Epacrideae, Polemoniaceae, &c.) elongated epidermal cells are not uncommon, the cells in some cases (species of *Lathyrus*, *Candollea*) being almost prosenchymatous. The long axis of these cells is usually parallel to the median vein of the leaf, although occasionally (*Silene fruticosa*, species of *Eutaxia* and *Trifolium*) transverse to it.

The **size**[1] **of the epidermal cells** often varies very considerably in the three directions of space. As a general rule, in the same species, the cells of the upper epidermis are larger than those of the lower epidermis. The extreme limits (i.e. very large or very small dimensions) in the size of the cells on one and the same surface of the leaf are at least of specific value, while variations of this feature within narrower limits occur in individuals of the same species, occupying different habitats (see Introduction, p. 9). A considerable development in the height of the epidermal cells is occasionally connected with both extremes of size.

A **small-celled** epidermis, as seen in surface-view, has been described in certain Capparideae, Vochysiaceae, Chlaenaceae, Malpighiaceae, Hippocrateaceae, Salvadoraceae, Chloranthaceae, Myristicaceae and Buxaceae; a **large-celled** epidermis, as regards all three dimensions, this feature being occasionally combined with a special development in the height of the cells, is found in certain Menispermaceae, Cistineae, Violarieae, Tremandreae, Elatineae, Sterculiaceae, Malpighiaceae, Geraniaceae, Rosaceae, Bruniaceae, Myrtaceae sens. str., Melastomaceae, Cucurbitaceae, Begoniaceae, Plumbagineae, Styraceae, Apocynaceae, Asclepiadeae, Gesneraceae, Verbenaceae and Illecebraceae; epidermal cells of considerable **height**, generally combined with a palisade-like shape of the cells, when seen in a transverse section of the leaf, have been observed in certain Anonaceae, Guttiferae, Dipterocarpeae, Rhaptopetalaceae, Malpighiaceae, Ilicineae, Celastrineae, Hippocrateaceae, Sapindaceae, Caesalpinieae, Chrysobalaneae, Saxifragaceae, Hamamelideae, Melastomaceae, Cornaceae, Candolleaceae, Vacciniaceae, Ericaceae, Epacrideae, Primulaceae, Bignoniaceae, Illecebraceae, Laurineae, Thymelaeaceae, Santalaceae and Buxaceae. In a few species of *Candollea* (Candolleaceae) the high epidermal cells, which have a rhombic outline or assume a fibrous form, are placed obliquely to the surface, and as a consequence the epidermis is 'apparently many-layered' in a transverse section of the leaf.

Further differences in the epidermis are connected with the structure of the cuticle and walls of the epidermal cells, and with the excretion of wax on the surface.

The **cuticle** varies in thickness and, as seen in surface-view, is either smooth or provided with granular or verrucose thickenings, or striated. The thickness of the cuticle as well as the degree of marking on its surface may in extreme cases be utilized for systematic purposes; in other cases a certain amount of discretion is necessary, i.e. these features should not be employed until abundant material of the species in question has been examined; the two features,

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[1] The variations in the sizes of the cells on the corresponding organs of one and the same genus (*Gunnera*) are often inconsiderable, even when there are great differences in the dimensions of the organs in question; for details, see Schnegg (in Flora, xc, 1902, p. 206 et seq.) and Amelung (in Flora, 1893, p. 208 et seq.).

moreover, are not always developed in the same way on the two surfaces of the leaf. A more important character from the systematic point of view is the kind of marking on the cuticle. This applies particularly to the **cuticular ridges or crests**, which are often of considerable height and occur on the flat surface of the epidermis (especially on the lower side of the leaf) in certain Capparideae, Dipterocarpeae, Malvaceae, Cyrilleae, Mimoseae, Rosaceae, Lythrarieae, Cacteae, Araliaceae, Vacciniaceae, Ericaceae, Sapotaceae (Fig. 117, p. 513), Styraceae, Apocynaceae, Euphorbiaceae and Ulmaceae; they are frequently the cause of the dull appearance of the surface of the leaf. Similar high cuticular ridges occasionally unite the papillae developed from the epidermal cells of the leaf, such papillae being provided with cuticular outgrowths in the form of a small crown or ridge (see the discussion of the papillae below). It remains to consider: (*a*) the occurrence of the 'cuticular layers,' which are more or less cuticularized and apposed to the cuticle on its inner side, (*b*) the penetration of the cuticle or of the cuticular layers into the lateral walls of the epidermal cells in the form of lamellae or pegs, and (*c*) similarly, the penetration of the cellulose-membrane into the cuticularized portion of the outer wall in the form of lamellae or pegs. The structural feature last named has been recorded chiefly in certain Papilionaceae belonging to the tribes Podalyrieae and Genisteae, as well as in certain Lythrarieae and Proteaceae, and commonly causes 'false pitting or internal striation' of the outer walls of the epidermal cells, when seen from the surface (see pp. 896, 897, &c.).

The thickness of the entire outer wall and of the lateral and inner walls varies in the same way as does the thickness of the cuticle. It is a familiar fact that strongly thickened walls constitute a peculiarity of many xerophilous species. Exceptionally **strong thickening of the inner walls** of the upper epidermal cells has been observed in certain Epacrideae and Euphorbiaceae; uniformly **sclerosed epidermal cells** occur in certain Menispermaceae, Capparideae, Ochnaceae, Sapindaceae, Melastomaceae, Candolleaceae (fibrous), Epacrideae, Thymelaeaceae and species of *Gonystylus*, while in certain Caesalpinieae, Vacciniaceae and Epacrideae the epidermal cells have the appearance of stone-cells only when seen from the surface. The lateral and inner walls, when strongly thickened, are for the most part pitted. A feature deserving quite special notice is the occurrence of distinct bordered pits side by side with simple pits on the lateral walls in certain species of *Candollea* (Candolleaceae). Pitting of the entire outer wall[1] is rare (Capparideae, Celastrineae, Hippocrateaceae, Sapindaceae); peculiar long, branched pit-canals have been observed in the outer walls in the genus *Mortonia* (Celastrineae). A commoner feature, found in species having undulated lateral walls, is the occurrence of so-called **marginal pits**, i.e. pits which traverse the outer walls, but are situated in the bays and often run obliquely towards the outside. Lignified **thickening bands** have been observed on the lateral walls in *Notouratea inundata*, Van Tieghem (Ochnaceae), spiral or reticulate thickening of the epidermal cells in the Order Vacciniaceae, and reticulate thickening of the outer walls in certain Ericaceae and Epacrideae. The exact chemical nature of the inner and lateral walls (regarding gelatinization, see § 2, p. 1074) may likewise be taken into consideration in systematic-anatomical investigations.

In many species the protective action of the cuticle is augmented by a considerable **excretion of wax**, which gives those particular parts of the plant (both leaves and stems) a glaucous or hoary appearance.

Such an excretion of wax is found in certain Magnoliaceae, Menispermaceae,

[1] Ambronn, Poren in den Aussenwänden von Epidermiszellen, in Pringsheim Jahrb., xiv, 1884, p. 82 et seq. and Tab. viii. Regarding sensitive pits in the tendrils of Cucurbitaceae, &c., see Haberlandt, Physiolog. Pflanzenanatomie, 1904, p. 509 et seq.; also under Cucurbitaceae, p. 939.

Papaveraceae, Cruciferae, Violarieae, Bixineae, Tamariscineae, Malvaceae, Zygophylleae, Aceraceae, Mimoseae, Rosaceae, Crassulaceae, Myrtaceae, Passifloraceae, Cacteae, Ficoideae, Compositae, Ericaceae, Vacciniaceae, Epacrideae, Asclepiadeae, Gentianeae, Solanaceae, Nyctagineae, Illecebraceae, Chenopodiaceae, Laurineae, Proteaceae, Thymelaeaceae, Euphorbiaceae and Salicineae. Concerning the varied nature of this excretion, see under the Orders cited, and De Bary, Vergl. Anat., p. 87 et seq.

A valuable specific character is afforded by the **papillose differentiation of the epidermal cells**[1]. This phenomenon is particularly common in the cells of the lower epidermis, but rarer in those of the upper epidermis; it is occasionally found on both sides of the leaf in one and the same species. The differentiation of papillae generally causes the surface of the leaf to have a dull appearance. In some cases the papillae are confined to the cells immediately surrounding the stomata or to the margin of the leaf. The papillae vary in the extent of their development and in their differentiation. One finds all stages, from the formation of distinct papillae down to a simple convex protrusion of the outer walls on the one hand, and culminating in simple unicellular hairs on the other. Epidermal cells, in which the outer walls are strongly arched outwards, may be described as subpapillose. The development of a typical papilla affects either the entire outer wall of the epidermal cell or merely its central portion. The length and shape of the papillae vary. Their walls may be either thin or thick; the short (and more rarely the long) papillae occasionally develop into solid pegs owing to secondary thickening of the cell-wall (in certain Polygaleae, Rosaceae, Ebenaceae (Fig. 118, p. 517), Proteaceae, Penaeaceae, *Geissoloma*, &c.). In some cases also the papillae form the centres for a radial striation of the epidermal cells. Special mention may be made of the relatively long and striated papillae, which are provided with a small cuticular crown and stand in connexion with one another by means of cuticular ridges, placed at right angles to the surface of the leaf (e.g. in certain Anonaceae, Sapindaceae, Papilionaceae, Araliaceae, Cornaceae, Ebenaceae, Fig. 118, p. 517, Styraceae, Oleaceae).

Papillose or subpapillose differentiation of the epidermal cells has been observed in certain species belonging to the following Orders or genera: Ranunculaceae, Magnoliaceae, Trochodendraceae, Lactoridaceae, Anonaceae, Menispermaceae, Berberideae, Nymphaeaceae, Papaveraceae, Capparideae, Violarieae, Bixineae, Pittosporeae, Polygaleae, Vochysiaceae, Caryophylleae, Tamariscineae, Hypericineae, Guttiferae, Ternstroemiaceae, Lineae, Malpighiaceae, Geraniaceae, Rutaceae, Simarubaceae, Ochnaceae, Burseraceae, Meliaceae, Olacineae, Celastrineae, Rhamneae, Ampelidaceae, Sapindaceae, *Bretschneidera*, Hippocastanaceae, Aceraceae, Staphyleaceae, Anacardiaceae, Connaraceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae, Crassulaceae, Hamamelideae, Bruniaceae, Halorageae, Combretaceae, Myrtaceae sens. str., Lecythidaceae, Melastomaceae, Lythrarieae, Passifloraceae, Cucurbitaceae, Begoniaceae, Ficoideae, Umbelliferae, Araliaceae, Cornaceae, Caprifoliaceae, Rubiaceae, Compositae, Campanulaceae (only isolated papillae), Ericaceae, Epacrideae, Diapensiaceae, Ebenaceae (Fig. 118), Styraceae, Oleaceae, Apocynaceae, Loganiaceae, Polemoniaceae (only isolated papillae), Boragineae, Convolvulaceae, Solanaceae, *Zombiana*, Gesneraceae, Bignoniaceae, Acanthaceae, Aristolochiaceae, Chloranthaceae, Piperaceae, Myristicaceae, Laurineae, Hernandiaceae, Proteaceae, Thymelaeaceae, Penaeaceae, *Geissoloma*, Santalaceae, Euphorbiaceae, Daphniphyllaceae, Ulmaceae, Moraceae, Thelygoneae, Myricaceae, Cupuliferae. For certain epidermal cells of the leaf, which are developed like bladders or hairs, see also §§ 2 and 31.

A feature, which can generally likewise be employed only for specific diagnosis, is afforded by the occurrence of thin **horizontal or vertical**

[1] Köhne, Vorkommen von Papillen u. oberseit. Spaltöffn., Mitteil. deutsch. dendrolog. Gesellsch., 1899, pp. 47–67; see also Köhne, *Fraxinus*-Arten, in Regel, Gartenflora, 1899, pp. 284–8.

division-walls in the epidermal cells in certain Celastrineae, Sapindaceae, Hippocastanaceae, Papilionaceae, Caesalpinieae, Mimoseae, Araliaceae, Loganiaceae and Moraceae; see also § 3, p. 1076.

Of **special contents found in the epidermal cells** we may in the first place mention the presence of chlorophyll[1], which occurs chiefly in species growing in shady or damp localities.

The species in question belong to the following Orders: Ranunculaceae, Geraniaceae (*Impatiens*, *Tropaeolum*), Ilicineae, Staphyleaceae (*Staphylea*), Droseraceae, Onagrarieae (*Epilobium*), Diapensiaceae, Solanaceae (*Datura* § *Brugmansia*), Scrophularineae, Lentibularieae, Pedalineae, Selagineae, Verbenaceae, Labiatae, Phytolaccaceae, Podostemaceae, Euphorbiaceae (*Mercurialis*), Thelygoneae, Ceratophylleae.

The occurrence of anthocyanin (widely distributed in the Begoniaceae and Gesneraceae) and tannin in the epidermis also requires to be taken into account. For the occurrence of oxalate of lime, see § 2; for sphaerocrystalline masses and other contents composed of organic substances, see §§ 23 and 25; for mucilage, see § 2; for other kinds of secretions, see § 14; and for cystoliths, see § 28.

Regarding incrustation of the walls of the epidermal cells, see §§ 26 and 27.

§ 2. Differentiation of the Simple Epidermis of the Leaf. In this section we shall discuss especially the differentiation of the epidermis of the leaf in so far as it is brought about by the occurrence of mucilaginous epidermal cells, of cells containing oxalate of lime, and of large epidermal cells, which either serve for the storage of water or are filled with brown contents in the dry leaf. Regarding epidermal idioblasts, which contain other kinds of secretion or are occupied by cystoliths, see §§ 14 and 28 respectively.

1. The **gelatinization of the epidermis of the leaf**[2], which serves for the storage of water, but occasionally occurs also in species from damp habitats, is a good specific character. Gelatinization usually affects only the inner walls of the epidermal cells, rarely the outer walls as well, and as a general rule is found more commonly on the upper than on the lower side of the leaf. Gelatinized epidermal cells are often distinguished by their large size; in such cases the mucilaginous portions of the inner walls, which are separated from the lumina of the cells by a cellulose-lamella and occasionally include further internal cellulose-lamellae, commonly penetrate into the mesophyll in a hemispherical or conical form, sometimes giving rise to transparent dots in the leaf. As a rule only isolated cells of the epidermis are mucilaginous, but occasionally there are groups of gelatinized cells of varying size or the entire epidermis is affected. In the cases last mentioned a regular **layer of mucilage** is produced below the upper epidermis, in the formation of which the adjacent walls of the subepidermal layer of cells may also play a part (in certain Menispermaceae, Rutaceae, Fig. 40, p. 175, Loganiaceae, Gentianeae and Euphorbiaceae; in the Gentianeae also beneath the epidermis of the stem).

Cells with gelatinized inner membranes have been observed in the integumental tissue (epidermis and hypoderm) in species of the following Orders or genera, as the case may be: Magnoliaceae, Anonaceae, Cruciferae, Resedaceae, Cistineae,

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[1] Stöhr, in Sitz.-Ber. Wiener Akad., lxxix, Abt. 1, 1879; and De Bary, Vergl. Anat., 1877, p. 70.

[2] Radlkofer, Monogr. *Serjania*, 1875, p. 100; Wallirzek, Membranschleime, in Pringsheim Jahrb., xxv, 1893, p. 209; Kruch, Epid. mucil., Ann. R. Ist. bot. di Roma, vi, 1896, 86 pp. and 2 Tab.

It may be well at this point to warn the reader against the confusion between gelatinized portions of the walls of the epidermis and the cells of a hypoderm,—an error which occurs over and over again in the literature.

Violarieae, Bixineae, Tremandreae, Vochysiaceae, Elatineae, Ternstroemiaceae, Dipterocarpeae, *Monotes*, Chlaenaceae, Malvaceae, Sterculiaceae, Tiliaceae, Lineae, Malpighiaceae, Rutaceae, Simarubaceae, Ochnaceae, Luxemburgiaceae, Burseraceae, Meliaceae, Chailletiaceae, Olacineae, Ilicineae, Cyrilleae, Celastrineae, Pentaphylacaceae, Rhamneae, Sapindaceae, Aceraceae, Staphyleaceae, Moringeae, Connaraceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae, Saxifragaceae, Hamamelideae, Rhizophoraceae, Melastomaceae, Lythrarieae, Onagrarieae, Samydaceae (only in *Gerrardina*), Turneraceae, Passifloraceae, Cornaceae, Ericaceae, Myrsineae, Sapotaceae, Gentianeae, Phytolaccaceae, Polygonaceae, Thymelaeaceae (Fig. 174, p. 717), *Gonystylus*, *Geissoloma*, Euphorbiaceae, Ulmaceae, Moraceae, Cupuliferae, Salicineae, Empetraceae.

Epidermal cells, in which the inner walls are swollen (e.g. in certain Samydaceae), must not be confused with gelatinized epidermal cells, even though in some respects they constitute a transition to the latter.

II. **Epidermal cells containing oxalate of lime** are rarely the cause of a differentiation of the epidermis of the leaf, this being the case only when the crystal-cells are distinguished from the remaining epidermal cells by their larger or smaller size and by their shape. The small **crystal-idioblasts** mostly appear round, when seen from the surface, and contain either a clustered or a solitary crystal; they are rarely isolated, being more commonly paired or united to form small groups; in the Papilionaceous genus *Stylosanthes* they have a polygonal outline and enclose a single rod-shaped or geniculate solitary crystal, the entire superficial layer of the integumental tissue on the lower side of the leaf (except for the stomata and their subsidiary cells) in this case being composed of such crystal-cells (Fig. 58, *B*, p. 265).

The large crystal-idioblasts, which in the 'Schlussbemerkungen' of the original German edition of this book (p. 908) were mentioned as occurring in certain Rutaceae and Euphorbiaceae, and are perhaps found in the same position also in other Orders, urgently require an investigation of their mode of development, in order to determine whether they really, or only apparently, belong to the epidermis.

The well-known crystal-cells of *Citrus*, which are wedged in between the epidermal cells on the two surfaces of the leaf, are subepidermal cells, which have penetrated into the epidermis by a process of sliding growth. This is likewise true of (*a*) the large cells with clustered crystals, found in *Dalechampia Roezliana*, and probably also the cells with clustered crystals in other Acalypheae; (*b*) the cells with clustered crystals, which occur in *Caperonia* and *Argyrothamnia*, the cells in this case already projecting somewhat after the manner of a hair; (*c*) the cells containing sphaerites, which are found in *Acalypha* and *Claoxylon*, the cells in question likewise projecting beyond the surface; and (*d*) the hairs with clustered crystals, recorded in *Fragariopsis* and *Plukenetia* (cf. pp. 1049, 1051, and § 31)[1].

In the following synopsis all the **forms, in which oxalate of lime occurs in the epidermis of the leaf,** are taken into consideration, whether the cells containing the crystals appear as idioblasts or not. The Orders, in which relatively small crystal-idioblasts have been observed, are provided with a * preceding the name of the Order; cr. indicates ordinary solitary crystals; clust. cr. = clustered crystals; S = crystal-sand; R = raphides; A = acicular crystals; P = small prismatic or rod-shaped crystals.

Oxalate of lime has been observed in the epidermis in the following Orders: Magnoliaceae? (cr.), Anonaceae (cr., clust. cr.), Fig. 6, *A* (p. 36), *Menispermaceae (A, P, cr.), Capparideae (P), *Canellaceae (cr., clust. cr.), *Bixineae (cr., clust. cr.), Guttiferae (clust. cr., P), Fig. 27, *C* (p. 122), *Ternstroemiaceae (cr., clust. cr.), Tiliaceae (clust. cr.), Lineae (cr.), Rutaceae (cr.), Simarubaceae (P), Olacineae (cr., clust.

[1] Guttenberg, Krystallzellen im Blatt von *Citrus*, Sitz.-Ber. Wiener Akad., cxi, Abt. 1, 1902, 18 pp., 1 Tab.; Knoll, Brennhaare der Euphorbiaceen-Gattungen *Dalechampia* und *Tragia*, Sitz.-Ber. Wiener Akad., cxiv, Abt. 1, 1905, 20 pp., 2 Tab.

cr.), *Celastrineae (cr., clust. cr.), *Hippocrateaceae (cr., clust. cr.), *Rhamneae (cr.), Sapindaceae (cr., clust. cr., S), Didiereae (clust. cr.), Aceraceae (cr.), *Papilionaceae (cr.), Fig. 58, *B* (p. 265), *Caesalpinieae (cr., clust. cr.), Mimoseae (cr.), Rhizophoraceae (cr., clust. cr.), Lecythidaceae, Melastomaceae (clust. cr.), Lythrarieae (cr.), *Samydaceae (cr., clust. cr.), Araliaceae (cr., clust. cr., P), Cornaceae (clust. cr.), Rubiaceae (R), Compositae (A), Epacrideae (cr.), Myrsineae (clust. cr., A, P), Sapotaceae (cr., clust. cr.), Styraceae (cr., clust. cr.), Oleaceae (A, P), Apocynaceae (cr.), Polemoniaceae (A), Solanaceae (S), Pedalineae, Acanthaceae (A), Myoporineae (clust. cr., A), Selagineae (P), *Piperaceae (*Symbryon*, clust. cr.), Chloranthaceae (small cr.), Laurineae (small cr.), Hernandiaceae (A, P), Proteaceae (cr.), Elaeagnaceae (A), Santalaceae (cr.), *Euphorbiaceae (cr., clust. cr.), *Daphniphyllaceae (clust. cr.), *Moraceae (cr., clust. cr., small cr.).

In certain Capparideae small crystals of **gypsum** are found in the epidermis of the leaf; these crystals can readily be distinguished from those of oxalate of lime by their chemical reactions (cf. § 25).

The mode of excretion of oxalate of lime in the epidermis is of varying systematic value. Special crystal-idioblasts are characteristic of species or genera. Among the Anonaceae oxalate of lime (either in the form of isolated or clustered crystals) is found in the epidermis in most of the species and therefore furnishes a useful character for the recognition of the Order. The excretion of oxalate of lime in the form of acicular crystals or of small prismatic or variously shaped crystals is, as experience has shown, of trifling systematic value.

III. In the third case a differentiation of the epidermis is brought about by the presence of **epidermal cells with wide lumina** among cells of the ordinary size; the large cells either store up water solely or are filled with special contents, which for the most part have a brown colour in the dry leaf. Such large epidermal cells, serving the purpose of water-storage, commonly form rows or are even arranged in a reticulate manner (Cruciferae, Fig. 14, p. 59); in certain Orders they are differentiated like bladders or hairs and occasionally give the living plant the appearance of being covered with drops of dew.

Epidermal cells, which have large lumina and store up water, but are not vesicular, are found among cells of the normal size in certain Cruciferae, Resedaceae, Elatineae and Malpighiaceae; vesicular epidermal cells (see also § 31) occur in certain Resedaceae, Caryophylleae, Portulaceae, Crassulaceae (Fig. 70, p. 321) and Ficoideae (Fig. 94, p. 416); tubular epidermal cells, filled with brown contents (see also § 14), are present in certain Violarieae, Geraniaceae, Saxifragaceae, Crassulaceae and Euphorbiaceae; elongated epidermal cells, described as mucilage-cells (see § 14), are found in *Tropaeolum* (Geraniaceae).

The following anatomical features remain to be mentioned at this point: the special epidermal cells, found in *Anamirta* and *Arcangelisia* (Menispermaceae, Fig. 7, *B*, p. 41) and in *Gonocaryum* (Olacineae, Fig. 48, p. 204), these cells functioning as hydathodes; the epidermis of the leaf of *Phyllachne* (Candolleaceae), the median and marginal portions of which are composed of prosenchymatous cells; and the peculiar groups of cells in the lower epidermis of species of *Limnanthemum* and *Villarsia* (Gentianeae).

§ 3. HYPODERM[1]. The water-storing epidermis is very frequently (especially on the upper side of the leaf) supplemented by a hypoderm, which likewise serves for the storage of water. A hypoderm may originate in two ways, viz. in some cases from the dermatogen, in other cases from the ground tissue. Our discussion should really be confined here to the hypoderm which is developed from the integumental tissue; such a hypoderm, together with the epidermis, is styled a 'many-layered epidermis' by Pfitzer, who reserves the term 'hypoderm' for the aqueous tissue arising from the mesophyll.

[1] See Pfitzer, Hautgewebe, in Pringsheim Jahrb., viii, 1872, p. 16 and Tab. vi.

Since, however, the source of the hypoderm is usually not recognizable in the fully developed leaf (as is shown, for example, by the close agreement between the hypoderm of *Ilex Aquifolium*, which is formed from the mesophyll, and that of *Ficus elastica*, which is developed from the epidermis), both kinds of hypoderm will be considered together here. The derivation of the hypoderm from the epidermis cannot be certainly established without a developmental investigation, except in those cases in which the lateral walls of the epidermal and hypodermal cells correspond with one another even in the mature leaf (e.g. in certain Connaraceae and Piperaceae, which have a typical two- or many-layered epidermis).

The **extent of development of the hypoderm** varies. In the simplest case there is merely a tendency towards the formation of a hypoderm, as shown by the appearance of division-walls, parallel to the surface of the leaf, in a varying number of the epidermal cells. When a parenchymatous hypoderm of one or more layers is developed, its cells often contrast with the epidermal cells by their considerable size. Hypodermal cells of the parenchymatous type have a polygonal or undulated outline in surface-view and walls of varying thickness; in those cases in which the latter are delicate, a loss of water results in a bellows-like folding of the lateral walls; in other cases the hypodermal cells are prismatic, the edges, which are placed at right angles to the surface of the leaf, being relatively strongly thickened. All these differences in the character of the hypodermal cells may be employed for systematic purposes (cf. the Introduction). The same applies to the development of the hypoderm on both sides or only on the upper or lower side of the leaf. Features deserving special mention are: the differentiation of a collenchymatous hypoderm in the axis of certain Cacteae (Fig. 90, p. 407); the presence of a hypoderm, developed like spongy tissue, in the leaf of *Oedematopus obovatus*, Tr. et Pl. (Guttiferae, Fig. 27, *B*, p. 122); and the occurrence of a **sclerotic hypoderm**, composed of fibrous or rod-shaped cells and occasionally connected with the sclerenchyma of the veins, in the leaves of certain species of *Berberis* and *Mahonia* (Berberideae), *Ochrocarpus* (Guttiferae), Elvasioideae, Van Tiegh. (Ochnaceae, the fibrous cells in this case being arranged transversely), *Euphoria* and *Litchi* (Sapindaceae), *Connarus* (Connaraceae), *Cephalostigma*, *Lightfootia*, *Merciera*, *Microdon*, *Prismatocarpus*, *Roella* and *Wahlenbergia* (Campanulaceae), Theophrasteae (here in almost all the species) and *Weigeltia* (Myrsineae), *Persea* (Laurineae), *Dryandra* (Proteaceae), and *Artocarpus* (Moraceae).

The appearance of **horizontal walls in the epidermal cells**, which leads to the differentiation of a two- or many-layered epidermis in the Orders marked with a *, has been observed in certain *Anonaceae, Menispermaceae, Bixineae, *Pittosporeae, Vochysiaceae, Malvaceae, Rhaptopetalaceae, Rutaceae, Ilicineae, *Celastrineae, *Rhamneae, Sapindaceae, Anacardiaceae ?, *Connaraceae, Saxifragaceae, *Crassulaceae, Rhizophoraceae, Melastomaceae, Lythrarieae, Cacteae (axis), Araliaceae, Cornaceae, Rubiaceae, Ericaceae, Epacrideae, Myrsineae, Sapotaceae, Salvadoraceae, Apocynaceae, Convolvulaceae, Bignoniaceae, Selagineae, *Piperaceae, Monimiaceae, Hernandiaceae, Moraceae, *Santalaceae.

Hypoderm is found in certain species of the following Orders or genera: Dilleniaceae, Magnoliaceae, Anonaceae, Menispermaceae, Berberideae, Capparideae, Violarieae, Canellaceae, Bixineae, Pittosporeae, Polygaleae, Vochysiaceae, Caryophylleae (observed only on the lower side), Portulaceae (*Lenzia*, only on the lower side), Hypericineae, Guttiferae, Ternstroemiaceae, *Strasburgeria*, *Ancistrocladus*, *Lophira*, *Monotes*, Chlaenaceae, Malvaceae, Sterculiaceae, Tiliaceae, Lineae, Malpighiaceae, Geraniaceae, Rutaceae, Simarubaceae, Ochnaceae, Burseraceae, Meliaceae, Chailletiaceae, Olacineae, Ilicineae, Celastrineae, Hippocrateaceae, Corynocarpaceae, Rhamneae, Sapindaceae, Didiereae, Anacardiaceae, Connaraceae, Papilionaceae, Caesalpinieae, Rosaceae, Saxifragaceae, Hamamelideae, Rhizophoraceae, Combretaceae, Myrtaceae sens. str., Lecythidaceae, Melastomaceae, Lythrarieae, Samydaceae, Passifloraceae, Cucurbitaceae, Begoniaceae, Datisceae, Cacteae (axis !),

Umbelliferae, Araliaceae, Cornaceae, Rubiaceae, Dipsaceae, Compositae, Campanulaceae, Vacciniaceae, Ericaceae, Epacrideae, Myrsineae, Sapotaceae, Ebenaceae, Styraceae, Oleaceae, Salvadoraceae, Apocynaceae, Asclepiadeae, Loganiaceae, Scrophularineae, Columelliaceae, Gesneraceae, Bignoniaceae, Acanthaceae, Verbenaceae, Labiatae, Nyctagineae, Amarantaceae, Phytolaccaceae, Polygonaceae, Nepenthaceae, Aristolochiaceae, Piperaceae (Fig. 168, p. 689), Chloranthaceae, Myristicaceae, Monimiaceae, Laurineae, Hernandiaceae, Gomortegaceae, Proteaceae, Elaeagnaceae, Loranthaceae, Santalaceae, Euphorbiaceae, Balanopseae, Ulmaceae, Moraceae, Urticeae, Leitnerieae, Myricaceae, Cupuliferae, Salicineae.

§ 4. STOMATA [1]. Among the manifold structural differences, which accompany the appearance of stomata, the mode of attachment of the epidermal cells surrounding the stomata to the pairs of guard-cells has proved to be of the greatest systematic importance. This feature is intimately connected with the course of **development of the stomata** from the cells of the dermatogen. As regards the mode of development we may, in agreement with Prantl, especially distinguish the following cases:

I. The mother-cell of the pair of guard-cells is formed by the first division-wall [2].

(*a*) The stomatal apparatus is completed, as soon as the pair of guard-cells is differentiated (**Ranunculaceous type**).

(*b*) In other cases accessory subsidiary cells are formed by secondary divisions in the surrounding cells.

(α) These divisions are confined to two neighbouring cells, situated at the sides of the mother-cell of the guard-cells (**false Rubiaceous type**; in many Monocotyledons, certain Portulaceae and Proteaceae), or

(β) they take place in four or more of the neighbouring cells (in Coniferae, Cycadeae, Monocotyledons, but also in *Ficus*).

II. The formation of the mother-cell of the guard-cells is preceded by the development of cells, subsidiary to the pair of guard-cells. The number of preparatory divisions varies.

(*a*) The preparatory divisions take place in two directions.

(α) The division-wall in the mother-cell of the guard-cells runs parallel to the walls, formed during the preparatory divisions. In this case the pairs of guard-cells are accompanied on either side (i.e. to the right and left) by one or more subsidiary cells, which are placed parallel to the pore (**Rubiaceous type**); the subsidiary cells in stomata of this type are either merely arranged parallel to the guard-cells (and also to one another, when more than two subsidiary cells are present), or partly surround one another; if, in the latter case, there are several subsidiary cells, a right-hand or left-hand subsidiary cell, as seen in surface-view, is alternately in part enveloped by one situated to the left or to the right respectively

[1] Strasburger, in Pringsheim Jahrb., v, 1866–7, p. 297 and Tab. xxxv–xlii; Prantl, in Flora, 1872, p. 305 and Tab. vi; De Bary, Vergl. Anat., 1877, p. 42; Immich, in Flora, 1887, p. 435; Vesque, in Bull. Soc. bot. de France, 1889, p. lxiii; Benecke, in Bot. Zeit., 1892, p. 521 and Tab. viii; [Tognini, in Atti Ist. bot. Pavia, ser. ii, vol. iv, 1894, 42 pp., 3 Tab.; abstr. in Just, 1894, p. 466, and Bot. Centralbl., Beib., 1894, p. 423]; Westermaier, in Festschrift für Schwendener, 1899, p. 63; Porsch, Der Spaltöffnungsapparat im Lichte der Phylogenie, Jena, 1905.

The term 'stomata' is used in this book to mean the same as 'pair of guard-cells.' When the epidermal cells surrounding the stomata are distinguished from the remaining cells of the epidermis by having a special shape or by their arrangement, they are spoken of as subsidiary cells, but in all other cases as neighbouring cells.

[2] In the following synopsis I have not included the case, in which the mother-cell of the pair of guard-cells arises directly from a cell of the dermatogen (regarding this point, see Tognini, loc. cit.); this has been recorded by Briosi and Tognini, but occurs very rarely.

(β) The division-wall in the mother-cell of the guard-cells is placed at right angles to the walls, formed during the preparatory divisions. The guard-cells are then accompanied by two or more subsidiary cells, which are arranged transversely with reference to the pore (**Caryophylleous type**). The mode of attachment of the subsidiary cells varies in the same way as in *α*.

(*b*) The preparatory divisions take place in three directions. This results in a stomatal apparatus, in which the guard-cells are surrounded by one or more rings, each consisting of three subsidiary cells (**Cruciferous type**).

The types just mentioned are occasionally characteristic of certain Orders, as indicated already by the names given to them by Vesque, while in other cases they are constant only for a genus or a group of species, or merely for a single species. Species are, moreover, known, in which two different types of stomata occur side by side on one and the same surface-section (see Selagineae, Verbenaceae, Labiatae, &c.). The combination of two types in the same stomatal apparatus is very rare (*Silvianthus*, Caprifoliaceae). Lastly, in employing these types for systematic purposes, it is important to bear in mind that, according to Tognini's investigations, the development of the stomata on the various organs (e.g. foliage-leaf, cotyledon, petal, stem) of the same plant-species may either be identical or may vary.

The **utilization of the different types of stomata for systematic purposes** is involved in great difficulties in practice, since these types can be determined with certainty only by a study of the course of development of the stomata, and are very commonly altogether unrecognizable in the mature leaf. In a fully grown leaf the true Rubiaceous type is often indistinguishable from the false one, and similarly the Ranunculaceous type can frequently not be distinguished from the Cruciferous type; a stomatal apparatus of the Ranunculaceous type, in which the edges of the U-shaped division-wall touch the common wall of contact between two epidermal cells, looks like a stomatal apparatus of the Caryophylleous type (**false Caryophylleous type**); a stomatal apparatus of the Caryophylleous type, in which the breadth of the pair of guard-cells is equivalent to that of the mother-cell of the whole stomatal apparatus, or in which the guard-cells have come to lie next to one of the longitudinal walls of the mother-cell, shows more than two cells in the immediate neighbourhood of the pair of guard-cells, and so on. In the following review it is therefore not possible to distinguish more than the following types: (1) Stomata without subsidiary cells, and having three or more neighbouring cells, arranged as in the Cruciferous or Ranunculaceous types; (2) Stomata with subsidiary cells, which are placed parallel to the pore (true and false Rubiaceous types); (3) Stomata with subsidiary cells lying transversely to the pore (true and false Caryophylleous types); (4) Stomata in which the Cruciferous type is prominent in the mature leaf.

The discrimination of the types of stomata themselves is a task, which is far from being completed; its solution, even though of no practical importance in the determination of plants, will nevertheless be of great value in connexion with the natural system of classification.

1. **Stomata having no subsidiary cells** and conforming to the Cruciferous or Ranunculaceous types[1] are found in: Ranunculaceae, Dilleniaceae *pro parte*, Trochodendraceae, Menispermaceae pro parte, Berberideae (subsidiary cells arranged in the form of a rosette in *Berberidopsis*), Nymphaeaceae, Sarraceniaceae, Papaveraceae, Fumariaceae, Cruciferae pro parte, Capparideae, Resedaceae, Cistineae,

[1] Under 1 I have also taken into consideration the few cases, in which more than three subsidiary cells are known to occur in contact with the pair of guard-cells.

Violarieae pro parte, Bixineae pro parte, Tremandreae, Polygaleae pro parte, Vochysiaceae pro parte, Frankeniaceae, Caryophylleae pro parte, Portulaceae pro parte, Tamariscineae pro parte, Elatineae, Hypericineae pro parte, Ternstroemiaceae pro parte (sometimes with subsidiary cells), *Strasburgeria*, Dipterocarpeae (in most cases), *Ancistrocladus*. *Lophira*, *Monotes*, Chlaenaceae, Malvaceae, Triplochitonaceae, Sterculiaceae, Tiliaceae, Humiriaceae pro parte, Zygophylleae, Geraniaceae pro parte, Rutaceae (in most cases, also subsid. cells in a rosette), Simarubaceae (in most cases), Burseraceae, Meliaceae, Olacineae pro parte, Octocnemaceae, Ilicineae, Cyrilleae, Celastrineae pro parte (also subsid. cells in a rosette), Hippocrateaceae, Stackhousieae, Rhamneae pro parte, Ampelidaceae, Sapindaceae (in most cases), Hippocastanaceae, Aceraceae, Melianthaceae, Staphyleaceae, Sabiaceae, Anacardiaceae, Moringeae, Connaraceae pro parte, Papilionaceae pro parte (also subsid. cells in a rosette), Caesalpinieae pro parte, Rosaceae pro parte, Crossosomataceae, Saxifragaceae pro parte, Crassulaceae (rare), Droseraceae (excl. *Byblis*), *Myrothamnus*, Bruniaceae, Halorageae, Rhizophoraceae, Combretaceae, Myrtaceae sens. str., Lecythidaceae pro parte, Melastomaceae pro parte, Lythrarieae pro parte (also subsid. cells in a rosette), Onagrarieae. Samydaceae pro parte, Loaseae, Turneraceae pro parte, Passifloraceae, Papayaceae, Cucurbitaceae, Datisceae, Ficoideae pro parte, Umbelliferae pro parte, Araliaceae pro parte, Cornaceae, Caprifoliaceae (excl. *Silvianthus*), Valerianeae, Dipsaceae pro parte, Calycereae, Compositae, Candolleaceae pro parte, Goodeniaceae pro parte, Campanulaceae incl. Lobeliaceae (excl. *Pentaphragma*), Ericaceae (in most cases), Epacrideae, Diapensiaceae, Lennoaceae, Plumbagineae pro parte, Primulaceae, Myrsineae, Sapotaceae pro parte, Ebenaceae, Styraceae pro parte, Oleaceae (in most cases), Salvadoraceae pro parte, Asclepiadeae pro parte, Loganiaceae pro parte, *Desfontainea*, *Plocosperma*, Gentianeae, Polemoniaceae, Hydrophyllaceae, Boragineae pro parte, Convolvulaceae pro parte, Solanaceae pro parte, *Lonchostoma*, Scrophularineae, Orobanchaceae, Lentibularieae pro parte, Columelliaceae, Gesneraceae pro parte, Bignoniaceae pro parte, Pedalineae pro parte, Myoporineae pro parte, *Zombiana*, Selagineae (on the same surface-section sometimes also subsid. cells, placed parallel or transversely to the pore), Verbenaceae pro parte, Labiatae pro parte, Plantagineae pro parte, Nyctagineae pro parte, Illecebraceae pro parte, Amarantaceae, Chenopodiaceae pro parte, Phytolaccaceae pro parte, Polygonaceae pro parte, Nepenthaceae, Aristolochiaceae, Piperaceae pro parte, Chloranthaceae pro parte (sometimes with subsid. cells arranged in a rosette, or with one or other subsidiary cell parallel to the pore), Monimiaceae pro parte, Hernandiaceae pro parte, Thymelaeaceae (papillose subsid. cells, arranged like a rosette, in certain species of *Daphne*), Penaeaceae, Elaeagnaceae, Santalaceae (sometimes side by side with stomata with parallel subsid. cells), *Myzodendron*, *Grubbia*, Euphorbiaceae pro parte, Buxaceae (also subsid. cells arranged in a rosette), Balanopseae, Ulmaceae pro parte, Cannabineae, Moraceae pro parte (rarely subsid. cells in a rosette), Urticeae pro parte, Platanaceae, Juglandeae, Myricaceae, Cupuliferae, Lacistemaceae, Empetraceae.

2. **Stomata with subsidiary cells, lying parallel to the pore,** occur in: Dilleniaceae pro parte, Calycanthaceae (Fig. 3, *B*, p. 25), Magnoliaceae (occasionally indistinct among the Schizandreae), Anonaceae, Menispermaceae (rare), Violarieae pro parte (often obscured), Canellaceae (partly obscured), Bixineae pro parte, Pittosporeae, Polygaleae pro parte, Vochysiaceae pro parte, Portulaceae (almost of general occurrence, true and false Rubiaceous types, Fig. 26, *B*, p. 112), Tamariscineae pro parte (?), Hypericineae pro parte, Guttiferae (Fig. 27, *C*, p. 122), Ternstroemiaceae pro parte, Dipterocarpeae pro parte (rare), Lineae, Humiriaceae pro parte (indistinct), Malpighiaceae, Geraniaceae pro parte, Rutaceae pro parte (rare), Simarubaceae (rare), Ochnaceae (always ?), Chailletiaceae (Fig. 46, p. 198), Olacineae pro parte, Celastrineae pro parte, Corynocarpaceae, Rhamneae pro parte, Sapindaceae pro parte (very rare), Coriarieae, Connaraceae pro parte, Papilionaceae pro parte, Caesalpinieae pro parte, Mimoseae, Rosaceae pro parte (Chrysobalaneae), Saxifragaceae pro parte, *Byblis*, Hamamelideae, *Ostrearia*, Myrtaceae sens. str. pro parte, Lecythidaceae pro parte, Melastomaceae pro parte, Samydaceae pro parte, Turneraceae pro parte, Cacteae, Ficoideae pro parte, Umbelliferae pro parte (with transitions to the Caryophylleous type), Araliaceae pro parte; Rubiaceae (Fig. 101, p. 446), Candolleaceae pro parte, Goodeniaceae pro parte (four subsidiary cells, as in *Tradescantia*), Vacciniaceae, Ericaceae pro parte (rare), Plumbagineae pro parte, Sapotaceae pro parte, Styraceae pro parte, Oleaceae pro parte (rare), Salvadoraceae pro parte, Apocynaceae (in most cases), Asclepiadeae (in most cases), Loganiaceae pro parte, Convolvulaceae pro parte, Bignoniaceae pro parte, Selagineae (see under 1), Nyctagineae pro parte,

Chenopodiaceae pro parte, Basellaceae, Phytolaccaceae pro parte, Batideae, Polygonaceae pro parte, Chloranthaceae pro parte, Myristicaceae, Monimiaceae pro parte, Laurineae, Hernandiaceae pro parte, Gomortegaceae, Proteaceae (false Rubiaceous type), Loranthaceae, Santalaceae (in most cases), *Champereia*, Euphorbiaceae pro parte, Daphniphyllaceae, Ulmaceae pro parte, Thelygoneae, Casuarineae (Fig. 186, p. 788), Salicineae.

3. **Stomata with subsidiary cells, lying transversely to the pore,** occur *in*: Caryophylleae pro parte (with exceptions, Fig. 25, C, p. 108), Melastomaceae pro parte (in part at least false Caryophylleous type, guard-cells occasionally almost completely surrounded by a single epidermal cell), Solanaceae pro parte (side by side with other types), Lentibularieae pro parte, Bignoniaceae pro parte, Acanthaceae (Fig. 144, *A*, p. 615), Verbenaceae pro parte, Labiatae pro parte (Fig. 152, *D*, p. 638), Plantagineae pro parte, Illecebraceae pro parte.

4. **Stomata, in which the pronounced Cruciferous type** is still recognizable in the mature leaf, are found in[1]: Cruciferae pro parte, Bixineae pro parte, Rhaptopetalaceae pro parte, Rhamneae pro parte, Staphyleaceae pro parte, Papilionaceae pro parte, Crassulaceae (in most cases, Fig. 70, *A*, p. 321), Lecythidaceae pro parte, Melastomaceae pro parte, Lythrarieae pro parte, Samydaceae pro parte, Begoniaceae, Araliaceae pro parte, Dipsaceae pro parte, *Pentaphragma* (Campanulaceae), *Brachynema*, Apocynaceae pro parte, Asclepiadeae pro parte, Loganiaceae pro parte, Boragineae pro parte, Convolvulaceae pro parte, Solanaceae pro parte, Gesneraceae pro parte, Bignoniaceae pro parte, Pedalineae pro parte, Myoporineae pro parte, Verbenaceae pro parte, Piperaceae pro parte, Euphorbiaceae pro parte, Moraceae pro parte, Urticeae pro parte.

The **shape of the guard-cells and the detailed structure of their walls** likewise appear to be features of great systematic importance, although hitherto little attention has been paid to them in papers dealing with systematic anatomy or, for the matter of that, in Dicotyledons generally. In this connexion the following features chiefly require to be considered: the contour of the pairs of guard-cells and the shape of the front cavity, when seen from the surface; the structure of the back cavity; the varied character and chemical nature of the unequal thickening of the walls of the guard-cells, and the corresponding differences in the shape of their lumina; lastly, the thickening ridges which arch over the front and back cavities, these ridges being for the most part strongly cuticularized, and the more or less strongly developed epidermal joints, found on either side of the guard-cells[2].

These features have been examined chiefly in the Monocotyledons, Gymnosperms and Mosses. The '**Gramineous type**,' first demonstrated by Schwendener in the Gramineae and Cyperaceae, is primarily characterized by the fact that the two guard-cells are dumbbell-shaped, i.e. they are low and flat in the middle region and enlarged at both ends. The outer and inner walls of the middle portion of the guard-cells are distinguished by having strong thickening ridges, which are not, as is elsewhere the case, approximated to the ventral side, but take up the entire breadth of the middle part and merge gradually into the thin walls of the enlarged ends of the guard-cells; as a result the middle part of the guard-cell, when seen in a transverse section, shows a slit-shaped lumen, which is placed transversely. The front cavity, as seen in surface-view, has an hexagonal outline with two longer sides, which are placed parallel to the direction of the pore. In addition, there are two subsidiary cells, which have thin walls and lie parallel to the pore.—The **Gymnospermous type** is particularly characterized by the fact that the

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[1] The following enumeration is not exhaustive, among other reasons, because, in the case of the material hitherto investigated, there are frequently enough no precise data, as to whether the three epidermal cells, surrounding the pair of guard-cells, are differentiated as subsidiary cells or not.

[2] Schwendener, Bau u. Mechanik d. Spaltöffn., Monatsber. Berliner Akad., 1881, p. 833; Mahlert, Anat. d. Laubbl. der Coniferen, &c., Bot. Centralbl., 1885, iv, p. 54; Haberlandt, Anat. u. Phy.. der Laubmoose, in Pringsheim Jahrb., xvii, 1886, p. 359 and Tab. xxvi; Schwendener, Spaltöffn. d. Gramineen u. Cyperaceen, Sitz.-Ber. Berliner Akad., 1889, p. 65; Copeland, Mechanism of stomata, Ann. of Bot., xvi, 1902, p. 327; Buck, Vergl. Anat. des Durchlüftungssyst., Diss., Freiburg i. Br., 1902; see especially Porsch, loc. cit., pp. 5, 21, and 33 et seq. and the literature cited in this paper.

guard-cells, as seen in a median transverse section, have the shape of an ellipse, the longitudinal axis of which is inclined approximately at an angle of 45° to the surface of the organ; other characteristic features are that the outer walls are mostly more strongly thickened than the inner walls, and that as a rule both walls—rarely the outer walls alone—include a lignified lamella.—The chief points to mention regarding the **Muscineous type** are that the thickening ridges on the front and back cavities are not typically differentiated, and that not uncommonly the guard-cells undergo fusion or the stomatal apparatus consists of three or four cells.

As has already been stated above, there are very few observations dealing with **Dicotyledons** from this point of view. The outline of the pair of guard-cells is generally elliptical or circular, the angular outline, found in the Papaveraceae and Fumariaceae, being remarkable. Thickening ridges, like the flaps of an envelope and resembling those present in Cyperaceae and Gramineae, are not at all rare in the guard-cells of Dicotyledons (e.g. in the Celastrineae according to Metz). Similar types of structure are produced by the presence of thin areas in the walls of the guard-cells, these thin portions being round or of other shapes and occupying the same polar position as in Gramineae, &c.; they occur in the Hippocrateaceous genera *Hippocratea* and *Salacia* (according to F. E. Fritsch), in many Ericaceae (according to Copeland), and in the Solanaceous genus *Trianaea* (here comma-shaped, according to Solereder). Other noteworthy features are constituted by the splitting of the outer appendicular ridges ('horns') on the guard-cells into two ridges, so that the front cavity becomes divided into an outer and an inner compartment (in certain Rhizophoraceae), and the deposition of cutine-lamellae, which correspond in all respects (see Porsch, loc. cit.) to the lignified lamellae of Gymnosperms (see above), in the outer and inner walls of the guard-cells in the Casuarineae. Schwendener refers also to a well-known type of structure, which is shown by the guard-cells of *Helleborus* and is figured in Sachs's and Haberlandt's textbooks; similarly Porsch, in the work cited in the footnote on p. 1079, describes a certain type of structure, exhibited by the guard-cells in the phyllodineous *Acacias* and in *Eucalyptus*.

At this point mention may also be made of peculiar processes on the walls of the guard-cells, as seen in surface-view; these processes take the form of lobes or have some other shape, and are found in certain Trochodendraceae, Berberideae, Geraniaceae (Fig. 39, *A*, p. 170), Sabiaceae (according to Dihm in Beih. z. Bot. Centralbl. xxi, Abt. 1, 1907), Laurineae and Penaeaceae (Fig. 175, p. 723); they occasionally occur also when the ordinary epidermal cells have jagged lateral walls with ridge-like thickenings in the angles. The distinctive shape of the guard-cells in certain floating plants (Nymphaeaceae, *Trapa*), when seen in a transverse section, is a biological feature; the closure of the pore in these forms is not brought about by contact of the protruding ventral walls, but by means of the outer cuticular ridges, which are much broadened.

The **size and number of the stomata**, especially in extreme cases (very large or very small stomata, occasionally even stomata of two sizes on the same leaf-surface; further, very many or very few stomata, which in the former case together with the neighbouring or subsidiary cells form almost the entire epidermal surface), may be employed for the diagnosis of species and occasionally even of more extensive taxonomic groups. A complete reduction of the stomata on the leaves or on other organs as well is found only in certain (not all) plants, which are submerged or lead a saprophytic or holoparasitic life. When stomata occur in such plants, they are mostly present only in small numbers, and as a rule merely owe their presence to inheritance; they are functionless, and in correspondence with this they often show a reduced type of structure and are occasionally provided with special arrangements for the closure of the pore [1].

Complete absence of stomata has been recorded: in the submerged leaves of *Ranunculus* § *Batrachium*, Nymphaeaceae pro parte and Halorageae pro parte; in *Aldrovanda*, Podostemaceae, and Ceratophylleae; in some of the saprophytic

[1] Porsch, Spaltöffnungsapparat, pp. 47–90; Porsch, Spaltöffnungsapparate submerser Pflanzenteile, Sitz.-Ber. Wiener Akad., cxii, Abt. 1, 1903, p. 97.

Monotropeae; and lastly, in the parasitic Orobanchaceae pro parte, Cytinaceae pro parte and Balanophoreae pro parte.

The **distribution of the stomata on the two surfaces of the leaf**[1] varies. It generally depends on the structure of the leaf, since leaves showing centric or homogeneous structure (especially those which are centric and are placed in a vertical position) in most cases bear stomata on both surfaces, while in leaves with typical bifacial structure the stomata are generally confined to the lower side. When stomata are present on both sides of the leaf, they are mostly more numerous on the lower than on the upper side, although the reverse is sometimes the case. Even though as a general rule these features are only of value for specific diagnosis, the exclusive occurrence of stomata on the lower side of the leaf is occasionally characteristic of entire Orders of varying magnitude (Dipterocarpeae, Hamamelideae, Begoniaceae). No great systematic value can be attributed to the occurrence of isolated stomata in the neighbourhood of the veins on the upper side of the leaf. The floating leaves found in some species of *Ranunculus*, the Nymphaeaceae (also on the leaves of *Nelumbium*, which are not floating, see Introduction, p. 9, footnote 1), *Callitriche* (Halorageae), *Trapa* (Onagrarieae), *Limnanthemum* (Gentianeae), *Trapella* (Pedalineae) and *Polygonum* naturally bear stomata only on the upper side. Even in terrestrial plants, however, the stomata are sometimes confined to the upper side of the leaf. In some cases (e.g. in the leaves of *Lepidophyllum* or *Passerina*, which are adpressed to the stem, or in the induplicate leaves of certain Podalyrieae and of *Hemiphragma*) this peculiar distribution is connected with the formation of spaces, which contain the stomata and are not reached by the wind; in other cases, as in the leaves of certain species of *Lythrum*, *Philoxerus*, *Pilea* and *Euphorbia*, it is related to the differentiation of aqueous tissue in the lower part of the leaf; in other cases again (species of *Geoffroya*) the restriction of the stomata to the upper side is inexplicable. The same arrangement of the stomata, combined with other remarkable peculiarities in their distribution, is found also in certain Mimoseae, where these features are connected with the assumption of the sleep-position. The curious distribution of the stomata in certain saxifrages may also be briefly referred to at this point.

Stomata, which are situated exclusively on the upper side, are found (apart from the floating leaves already discussed) in the following land-plants: Antarctic species of *Caltha* (which have curiously shaped leaves), species of *Viola*, species of *Myricaria* and *Tamarix* (Tamariscineae), *Geoffroya spinosa*, Jacq. and species of *Dillwynia*, *Eutaxia*, *Pultenaea*, *Coelidium* (Papilionaceae), certain Mimoseae, species of *Brunia ?*, *Lonchostoma*, *Pseudobaeckea* and *Raspalia* (Bruniaceae), *Epilobium crassum*, Hook. f. (Onagrarieae), species of *Candollea* (Candolleaceae), *Hedraeanthus Pumilio*, Porta (Campanulaceae), *Lepidophyllum* (Compositae), *Cassiope* (Ericaceae), *Leucopogon* (Epacrideae), *Hemiphragma* and *Lathraea* (in the latter genus on the 'scale-leaves,' Scrophularineae), *Philoxerus* (Amarantaceae), *Passerina* (Thymelaeaceae), *Euphorbia buxifolia*, *Pilea serpyllifolia* (Urticeae).

The **arrangement of the stomata with respect to one another**, as seen in surface-view, is well known to be quite irregular in most of the Dicotyledons. In exceptional cases the stomata lie with their pores directed parallel to one another, and at the same time parallel to the median vein of the leaf, as is the general rule among Monocotyledons; such an arrangement occurs chiefly in species having narrow leaves or leaflets. Another specially remarkable case is obtained, when the pores of the stomata are placed parallel to one another, but at the same time lie transversely to the midrib of the leaf; and it may at once be added, that, when stomata are present on the axis of such plants, they are placed transversely to the vertical direction.

[1] Fr. Darwin, Bloom on leaves and distribution of the stomata, Journ. Linn. Soc., xxii, 1887, p. 99; Köhne, Oberseit. Spaltöffn. auf Laubholzgew., Mitteil. deutsch. dendrolog. Gesellsch., 1899, p. 47.

Stomata, which have their pores directed parallel to one another and to the midrib of the leaf, have been observed in certain: Mimoseae (common), Bruniaceae, Melastomaceae, Cacteae (on the stem parallel to the longitudinal axis of the shoot), Candolleaceae, Campanulaceae, Epacrideae (in almost all the species), Plumbagineae, Loganiaceae, Polemoniaceae, Chenopodiaceae, Proteaceae, Santalaceae, *Myzodendron*; **stomata, which are arranged parallel to one another, but lie transversely to the midrib of the leaf** or to the vertical direction in the axis, as the case may be, are found in certain: Polygaleae (*Krameria* pro parte, leaf), Tamariscineae (leaf), *Balanites* (axis), Rhamneae (axis of *Colletia*, according to Pfitzer), Staphyleaceae (axis of *Staphylea pinnata*, according to De Bary), Papilionaceae (leaf in *Anarthrophyllum*, *Eutaxia* and *Latrobea*, axis in *Daviesia*, phylloclades and branches respectively in *Carmichaelia* and *Alhagi*), Bruniaceae (*Brunia* and *Staavia*, leaf), Cacteae (axis), Ficoideae (*Mesembryanthemum*, leaf), Epacrideae (*Lysinema*, leaf), Chenopodiaceae (leaf in *Suaeda*, *Salsola*, *Camphorosma*, *Echinopsilon*, *Halogeton*, *Traganum*, and axis in *Camphorosma*, *Salicornia*, *Suaeda*), Batideae (leaf and axis), Nepenthaceae pro parte, Laurineae (leaf and axis of *Cassytha*), Loranthaceae (leaf and axis of *Nuytsia*, and axis of other Loranthaceous genera), Santalaceae (commonly on the branches and also on the leaves[1]), Euphorbiaceae (axis of succulent *Euphorbias*), Casuarineae (sheaths and branches, Fig. 186, p. 788).

The **combination of stomata to form groups** is not very common. Such groups are found in the first place in certain Cruciferae, where they are due to the differentiation of the epidermis of the leaf into cells with large lumina and a reticulate distribution, and cells of the normal size, which constitute the subsidiary cells of the stomata. **Stomatal groups** are likewise present **on the surface of the leaf** in *Macrococculus* (Menispermaceae), species of *Soulamea* and *Castela* (Simarubaceae), species of *Euchresta* (Papilionaceae), species of *Saxifraga* and *Chrysosplenium*, species of *Calycogonium*, *Leandra* and *Ossaea* (Melastomaceae), certain *Begonias* (Fig. 87, *A*, p. 400), all the species of *Pagamea* (Rubiaceae) and *Napeanthus* (Gesneraceae), and in *Ficus gibbosa*, Bl.; and **in small pits** in the surface of the leaf in *Sarcolaena* and *Schizolaena* (Chlaenaceae, Fig. 33, p. 145), *Soulamea Pancheri*, Brongn. et Gris (Simarubaceae), *Trichouratea subvelutina*, Van Tiegh. (Ochnaceae), *Akania* (Staphyleaceae), *Mouriria* (Melastomaceae, Fig. 78, p. 359), *Nerium* (Apocynaceae), species of *Banksia* and *Dryandra* (Proteaceae), and species of *Ficus*[2]. Lastly, we can also speak of stomatal groups when the network of the veins projects strongly on the lower side of the leaf and the stomata are confined to the depressed portions of the surface. In connexion with our discussion of the stomatal pits (crypts), we may notice the occurrence of furrows occupied by stomata in rolled leaves and on the assimilating stems of plants having reduced leaves (e.g. in certain Papilionaceae, Casuarineae, &c.), whilst with the stomatal groups situated on the surface of the leaf we may class the arrangement of the stomata in longitudinal zones on the leaves of certain species of *Candollea* (Candolleaceae).

Other points of difference are connected with the varying **position of the guard-cells with respect to the neighbouring epidermal cells,** a feature which in most cases may be regarded as a measure of the humidity of the habitat in which the species grows. The guard-cells may either lie on a level with the epidermal cells or project to a marked extent, the latter being especially the case in species from damp localities, in species in which the stomata are contained in small pits, or in species which are protected from desiccation by the possession of a very dense hairy covering; in other cases again the guard-cells are sunk below the surface, this feature being found chiefly in species from dry habitats. The elevation of the stomata is particularly marked in

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[1] See also De Bary, Vergl. Anat., 1877, p. 48.

[2] Haberlandt (Physiol. Pflanzenanat., 1904) incorrectly ascribes small stomatal pits, like those of the Oleander, also to *Coscinium* (Menispermaceae).

the veins of the leaf of *Santiria* (Burseraceae, Fig. 43, p. 191), and in *Cineraria cruenta* (Compositae), certain species of *Cordia*, in the leaves of *Fabiana* (Solanaceae), which are covered with varnish, and on the stems of certain Cucurbitaceae. The depression of the guard-cells is effected either (*a*) by the differentiation of a thick outer wall on the epidermis, which is accompanied by a correspondingly strong development of cuticular crests, or (*b*) simply by the depression of the guard-cells (in some cases together with their subsidiary cells) beneath the neighbouring epidermal cells, or (*c*) by a more or less pronounced protrusion of the epidermal cells adjoining the guard-cells or subsidiary cells, which leads to the formation of a chimney-shaped outer respiratory cavity of varying shape and often of great depth[1]. The depression of the stomata in certain Thymelaeaceae and certain species of *Jacksonia* (Papilionaceae) is of a very peculiar character, and may therefore find special mention; in the former case the stomata occur singly at the base of lageniform pits, the wall of which is formed by the elongation of the 6–10 neighbouring cells surrounding the guard-cells (Fig. 174, p. 717), while in the species of *Jacksonia* the stomata together with their subsidiary cells are sunk in deep pits on the surface of the stem, each pit being closed by a clothing hair. Regarding certain Sapindaceae and Umbelliferae, see pp. 228 and 420.

'Plugged' stomata, which have long been known to occur in the Coniferae, have recently[2] been demonstrated in the Monocotyledons and Dicotyledons. They do not, however, possess great systematic value, since they are not always of constant occurrence in one and the same species, and are often found only on certain parts of the plant. In stomata of this kind the outer respiratory cavity (vestibule) is filled with a resinous mass, which interferes with the process of transpiration and the exchange of gases as a whole.

The same effect is produced by the peculiar thickenings found in certain Epacrideae (Fig. 111, p. 492) on those walls of the subsidiary cells, which border on the inner respiratory cavity. Finally, stomata may be put completely out of action by a local development of cork beneath the pairs of guard-cells; this ultimately leads to the formation of what are called cork-warts; for the cork-warts on the leaf, see § 39.

Twin-stomata (i.e. pairs of stomata lying side by side and touching one another by one of their longitudinal walls) now and then occur together with solitary stomata on the same surface of the leaf, but they are no doubt merely casual structures and have no systematic value.

§ 5. WATER-PORES[3]. Water-pores (i.e. open stomata, which function as hydathodes) occur singly or in groups on the leaf-teeth of many plants (cf. § 35, and the descriptions of the Orders there enumerated), or are found near the margin of the leaf (as in certain Geraniaceae, Begoniaceae, and Campanulaceae) or above the points of intersection of the veins of the leaf (as in certain Nymphaeaceae). They are distinguished sometimes by small dimensions, sometimes by considerable size[4]. The water-pores of the Lobeliaceae are particularly remarkable in that their pore is closed by the cuticle, a rather thick and cuticularized ridge penetrating from the latter into the cavity of the pore

[1] See Tschirch, Bez. des anat. Baues, &c., Linnaea, xliii, 1881, p. 323 and Tab. ii.

[2] Wulff, Verstopfte Spaltöffn., Österreich. bot. Zeitschr., 1898, pp. 201, 252 and 298, Tab. viii.

[3] Volkens, Wasserausscheidung, Jahrb. Berliner Garten, ii, 1883, p. 166; Haberlandt, Wassersec. u. absorb. Org., Sitz.-Ber. Wiener Akad., ciii and civ, Abt. 1, 1894 and 1895, pp. 489 and 55 respectively; Haberlandt, Hydathoden, Ber. deutsch. bot. Gesellsch., 1894, p. 367; Nestler, Wasserspalten, Nova Acta Leopold., lxiv, 1894, p. 143; Spanjer, Wasserapparate, Bot. Zeit., 1898, i, p. 35; Minden, Wassersec. Org., Bibl. Bot., Heft 46, 1899.

[4] It remains an open question, whether the pairs of guard-cells, which occur in many plants, and are distinguished from other stomata on the same surface of the leaf by their often considerable size, are invariably of the nature of water-pores.

('stomates aquifères septés')[1]. Beneath the water-pores one finds either the ordinary tissue of the mesophyll containing the termination of a vascular bundle, or a special thin-walled tissue (epithema), provided with intercellular spaces and enveloping the termination of the bundle. From the systematic point of view we may notice that the presence of water-pores constitutes a feature characteristic of the Menyanthoideae in contrast to the Gentianoideae. The water-pores, found in certain Crassulaceae, Moraceae and Urticeae, deserve special mention; they are united to form groups and are recognizable with the naked eye or with the help of a lens as small spots on the surface of the leaf. We may also refer to the groups of water-pores, found in certain species of *Saxifraga* (Fig. 66, p. 313), where they function as **chalk-glands** and have long been employed as a specific character by systematists.

With the water-pores we may class the **apical pores**[2] occurring at the tip of the leaf in various Dicotyledonous water-plants. They serve for the excretion of water and arise by the breaking down of the cells, situated above the terminations of the veins (mainly epidermal cells, but occasionally water-pores as well).

Small pits (which do not contain water-pores, but are formed by special epidermal cells surmounting the termination of a vascular bundle), such as occur in certain Ferns, have not been observed either in Dicotyledons or Monocotyledons. Regarding special epidermal cells, functioning as hydathodes and found in certain Menispermaceae and Olacineae, see the end of § 2, p. 1076; for the epidermal chalk- and salt-glands of the Frankeniaceae, Tamariscineae and Plumbaginaceae, see § 37; for peltate glands, secreting water and occurring in certain Rhinanthaceae and in *Monophyllaea* (Gesneraceae), see § 34 under I, b. Trichomes, which, in correspondence with their outward form, are described as clothing or glandular hairs in descriptive anatomy, may also function as hydathodes (see § 29).

§ 6. Mesophyll, Palisade and Spongy Tissues[3]. The influence of the surrounding medium on the structure of the leaf (i.e. the bifacial (dorsiventral) or centric (isolateral) development of the mesophyll and the detailed differentiation of its cells) has already been discussed in the Introduction, and in this connexion mention was likewise made of the variability of these structural features in one and the same species (see Introduction, pp. 6 and 10). In spite of this fact, these features may be employed for systematic purposes, and in the first place for specific diagnosis, provided their constancy is sufficiently established. This applies especially to the **structure of the leaf**, which we may distinguish as bifacial (palisade-tissue on the upper, spongy tissue on the lower side), subcentric to centric (palisade-tissue on both sides, occasionally forming the whole of the mesophyll) and homogeneous (mesophyll showing no differentiation into palisade and spongy tissues); occasionally the structure of the leaf is constant even in all the members of a small Order (Hamamelideae with bifacial structure). The most important features to notice in the structure of the **palisade-tissue** are the following: the regular or irregular stratification of the layers of palisade-cells, the cells of the same layer in the latter case not being of equal length, and superposed cells occasionally appearing to be derived from a single much elongated palisade-cell by transverse division; the number of layers constituting the

[1] Tswett, Hydathodes, &c., Journ. de bot., 1907, p. 305.

[2] Weinrowsky, Scheitelöffn. bei Wasserpfl., Diss., Berlin, 1898 (also in Fünfstück, Beitr., iii); see also Minden, loc. cit.

[3] Haberlandt, Assimilat. Gewebesyst., in Pringsheim Jahrb., xiii, 1882, p. 74 and Tab. iii–viii, and Ber. deutsch. bot. Gesellsch., 1886, p. 206; Stahl, Einfl. d. sonn. und schatt. Standorts, &c., Zeitschr. f. Naturw., Jena, 1883; Heinricher, Isolat. Blattbau, in Pringsheim Jahrb., xv, 1884, p. 502 and Tab. xxvii–xxxi; Loebel, Anat. d. Laubbl., loc. cit., xx, 1889, p. 38 and Tab. i–iii; Buck, Vergl. Anat. d. Durchlüftungssyst., Diss., Freiburg i. Br., 1902, p. 74; Schwartz-Clements, Relat. of leaf-struct. to phys. factors, Transact. Americ. Microscop. Soc., 1905, p. 19.

palisade-tissue; the shape of the palisade-cells (long and narrow cells, short and broad cells, 'funnel-cells,' and arm-palisade cells; for the latter, see also below); the relative extent to which the palisade-tissue, as compared with the spongy tissue, participates in the formation of the mesophyll. In the structure of the **spongy tissue** important characters are afforded by the varied arrangement (stratified or irregular) and shape (rounded cells, cells provided with several arms of varying length, cells with flat or with spreading arms, i.e. with arms developed parallel to the surface of the leaf only or radiating out in all directions) of the cells, and the consequent variations in the nature and size of the intercellular spaces.

Rolled leaves[1] generally show a distribution of palisade and spongy tissue which differs from that normally found, in so far as palisade-tissue is mostly developed in all those parts of the leaf which are turned towards the light, while spongy tissue occurs on the surface of the furrows, present on the upper or lower side of the leaf. The leaves of certain Tamariscineae, which are reduced to leaf-sheaths, and the leaves of certain Compositae, &c., which are adpressed to the axis and generally have their stomata restricted to the upper epidermis (cf. § 4), resemble those rolled leaves, which have a furrow on their upper side, in the development of palisade parenchyma only on the lower side of the leaf, which is turned towards the light.

In addition to the palisade and spongy tissues, which contain chlorophyll, **aqueous tissue** with little or no chlorophyll plays a part in the formation of the mesophyll, especially in thick and fleshy leaves. The differentiation of hypodermal aqueous tissue of varying thickness, but belonging to the mesophyll, as shown by a study of its development, has already been discussed in § 3. In other cases the aqueous tissue, the cells of which may have thin or thick walls, forms a middle layer (sometimes differentiated like a pith) in the leaf, or composes almost the entire mesophyll, so that the assimilatory tissue is crowded into the middle of the leaf; in the latter case the assimilatory tissue sometimes merely envelops the sheaths of the veins in the form of a rosette (Portulaceae, Fig. 26, *A*, p. 112, Chenopodiaceae, Fig. 158, p. 656). The occurrence of a tanniniferous middle layer, which therefore has a brown colour in the dry leaf, is characteristic of certain plants (Anonaceae, Sapindaceae, Papilionaceae, Mimoseae, Rubiaceae, and no doubt other Orders as well).

As regards the **special structural features presented by the palisade-tissue**, we may first deal with the occurrence of funnel-cells, arm-palisade cells, and conjugate cells as component elements of this tissue. Funnel-cells are short palisade-cells, which are narrowed down at their lower end in the form of a blunt cone; they are characteristic of plants inhabiting moist localities (occurring for example in certain Gesneraceae and Piperaceae). Cells having a similar shape ('collecting cells') are also found in the interior of the mesophyll, adjacent to the typical palisade-parenchyma. A more important systematic feature appears to be constituted by arm-palisade parenchyma, in which the elements, as seen in a transverse section of the leaf, are not single cells independent of one another, but the arms of what are called arm-palisade cells. The latter, or rather their individual branches, may be either long or (as in most cases) short, while the number of the branches is two or more. In conjugate palisade-cells the longitudinal walls are provided with two or more small papillose protusions, which enter into connexion (conjugate) with one another in neighbouring cells. This type of structure has been observed mainly

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[1] Rolled leaves have been observed in the following Orders: Berberideae, Frankeniaceae, Tremandreae, Polygaleae, Hypericineae, Lineae, Geraniaceae, Rhamneae, Papilionaceae, Rosaceae, Rubiaceae, Compositae, Ericaceae, Epacrideae, Primulaceae, Scrophularineae, Empetraceae (Fig. 188, p. 800), Euphorbiaceae; see also Meigen, in Engler, Bot. Jahrb., xviii, 1894.

in the short palisade-tissue found on the lower side of subcentric leaves and occasionally extends also to layers of the adjoining spongy tissue.

Arm-palisade tissue is found not only in the Filices, Equisetaceae, Coniferae and Gramineae, but also in a number of Dicotyledons, viz.: *Aconitum*, *Adonis*, *Anemone*, *Caltha*, *Clematis*, *Delphinium*, *Nigella*, *Paeonia* and *Trollius* (Ranunculaceae), *Euptelea* (Trochodendraceae), *Disciphania* (Menispermaceae), *Saurauja* (Ternstroemiaceae, Fig. 29, *A*, p. 129), *Meliosma* (Sabiaceae), *Casearia* (Samydaceae, only faint indications), *Acanthopanax*, *Cussonia*, *Gilibertia*, and *Pseudopanax* (Araliaceae), *Adoxa*, *Sambucus* and *Viburnum* (Caprifoliaceae), *Candollea* (Candolleaceae), numerous Campanulaceae, *Lysimachia* and *Trientalis* (Primulaceae), *Symplocos* (Styraceae), *Protoschwenkia* and *Schwenkia* (Solanaceae), *Ascarina*, *Chloranthus*, and *Hedyosmum* (Chloranthaceae), *Phyllanthus* (Euphorbiaceae) and *Parartocarpus* (Moraceae). The systematic value of this feature is either restricted to species (e.g. in *Anemone* and *Phyllanthus*) or to genera (e.g. *Meliosma*).

The fine bellows-like folding, which may commonly be observed in herbarium-material on the lateral walls of the palisade-tissue, and is met with also in the hypoderm, is a result of the participation of these tissues in the storage of water; the same explanation applies to the occurrence of ridge-like or reticulate thickenings on the walls of the palisade-cells in certain plants, e.g. species of *Clusia* (Guttiferae, Fig. 27, *A*, p. 122), *Meriania* and *Graffenrieda* (Melastomaceae), *Candollea* (Candolleaceae), *Sophoclesia* (Vacciniaceae), *Dyssochroma*, *Juanulloa*, and *Markea* (Solanaceae).

In certain species of *Reynosia* and *Sarcomphalus* (Rhamneae), *Lightfootia* (Campanulaceae) and *Artocarpus* and *Ficus* (Moraceae) the cells of the **spongy tissue** have a very remarkable hypha-like form.

In the species of *Buxus*, belonging to the section *Eubuxus*, the sudden transition from assimilatory tissue with rounded lumina (which adjoins the palisade-tissue on its lower side) to spongy tissue with large lacunae leads to the splitting of the leaf into two corresponding halves.

Another structural feature of the mesophyll, which may be mentioned at this point and can be employed for systematic purposes, is the occurrence of **peculiar thickenings or swellings**, which are restricted to certain points of the cell-wall, and are found, **especially in the spongy tissue**, but also on the upper and lower walls of the palisade-cells, in many Menispermaceae and Melastomaceae, in certain Loganiaceae and in *Melananthus guatemalensis*, Solered. (Solanaceae); these thickenings have a mucilaginous appearance and more or less recall the structure of the wall in collenchymatous tissue. They certainly do not differ very materially from the gelatinized portions of a cell-wall, especially as subepidermal **layers of mucilage** occur side by side with them in the same species (e.g. in certain Menispermaceae and Loganiaceae); both the inner walls of the epidermal cells and the adjoining walls of the palisade-tissue are concerned in the formation of these mucilage-layers. Gelatinization of the spongy tissue (differing from the swellings just discussed ?) has been recorded in numerous Apocynaceae and in *Sclerophylax* (Solanaceae), and gelatinization of the entire mesophyll in certain species of *Gentiana*. It remains to mention the **cracks due to drying**[1], which are formed in certain species by a process of fissuring owing to the drying of the leaf, and frequently give rise to transparent dots (Capparideae, Burseraceae, Sapindaceae, Connaraceae, Cornaceae, Bignoniaceae, Verbenaceae).

For the occurrence of sclerosed cells in the mesophyll, see § 9, p. 1090; for the occurrence of secretory organs, see § 14 et seq., and of oxalate of lime and other contents, see § 22 et seq.

[1] See Blenk, in Flora, 1884; and Radlkofer, in Sitz.-Ber. Münch. Akad., 1886, p. 341.

§ 7. STRUCTURE OF THE VEINS OF THE LEAF. The following features can be used for systematic purposes: the appearance of the fibrovascular system, as seen in transverse section; the presence or absence of mechanical tissue or of a protective sheath in connexion with the vascular system; and the structure of the tissue, developed above and below the vascular system. When the vascular system of the veins is surrounded on all sides by assimilatory tissue, we may speak of 'embedded veins,' in contrast to 'vertically transcurrent veins,' in which a special colourless tissue (' Begleitgewebe ') adjoins the vascular system on its upper and lower side.

When undertaking a comparative investigation, the observations should, in the first place, invariably be based on veins of the same order, and also on a transverse section taken through a definite part of the vein in question. For, in the case of the principal vein and all the larger lateral veins, the appearance of the fibrovascular system in a transverse section and the differentiation of the mechanical tissue accompanying the vascular bundles generally differ according as the vein is examined at its base or in its further course; and in the case of the smaller veins this applies at least to the latter feature. A further point to be taken into account is the thickness of the veins. Lateral veins of the same order may vary in thickness and may consequently show a different structure at corresponding points in allied species, especially if the latter have leaves of different sizes. The systematic employment of the features in question requires a critical judgement, and has on the whole been little attempted hitherto, mainly owing to the amount of labour involved, and in view of the fact that the results to be obtained are not very considerable.

Among features, which are more easily determined, the following chiefly come into consideration for the purposes of anatomical diagnosis: the embedded character or vertical transcurrence of the medium-sized and smaller veins; the presence or absence of a strongly developed mass of mechanical tissue (sclerenchyma) in connexion with the vascular bundles; and the occurrence of a sheath of large cells around the vascular bundles. **Vertical transcurrence of the smaller veins** is often characteristic of a genus (see for instance Epacrideae, p. 492) and occasionally even of an Order (Dipterocarpeae); such veins give rise to a vascular network, which is visible even to the naked eye. The diverse ways, in which transcurrence is effected, are generally only of specific value; the veins may be vertically transcurrent by means of colourless parenchyma, the walls of which are either thin or slightly lignified or sclerosed or collenchymatous, or by means of plates of sclerenchymatous fibres, which sometimes spread out beneath the epidermis of the leaf like a T-girder or may resemble a hypoderm. When sclerenchymatous tissue is present, the extreme cases (on the one hand a more or less closed ring or at least well-developed arcs of sclerenchyma, on the other hand occurrence of mere isolated sclerenchymatous cells or complete absence of this tissue) are chiefly to be considered. In the majority of cases this biological feature is only of specific value (see the Introduction, p. 8 et seq.), but there are entire Orders (Begoniaceae), in which sclerenchyma is either completely wanting in the veins or is found only in a few species, and then mostly in small quantity. **Sheaths of large parenchymatous cells**[1] occur more commonly in Monocotyledons than in Dicotyledons; they function as a protective envelope and to a less extent for the conduction of food-substances; such sheaths have been observed in the following Dicotyledons: *Portulaca* (Portulaceae), *Tribulus* (Zygophylleae, here with thick pitted walls, Fig. 38, *D*, p. 168), certain Papilionaceae, *Pectis humifusa*, Sw. (Compositae), *Heliotropium fruticosum*, L. (Boragineae), certain Polemoniaceae (cells thickened in a U-shaped manner in *Gilia pungens*, Hook., suberized cells in other cases), Nyctagineae, Amarantaceae (Fig. 156, *A*, *B*, p. 652), Chenopodiaceae (Fig. 158, p. 656) and

[1] Schubert, Parenchymscheiden in den Bl., Bot. Centralbl., 1897, iii, p. 307.

Euphorbiaceae. In some of these plants (*Portulaca*, *Pectis*, Amarantaceae, Euphorbiaceae) the sheath is enveloped by radially arranged palisade-tissue. In connexion with our discussion of the parenchyma-sheaths we may mention the occurrence of a special layer of cells, observed by Van Tieghem in the veins of the leaf (chiefly in the Ochnaceae and Luxemburgiaceae, but also in the Lineae) and styled by him '**cristarque**[1];' the 'cristarque' is separated from the epidermis by a single cell-layer and is composed of cells, which are thickened in the shape of a horseshoe, and enclose a clustered or solitary crystal of oxalate of lime; in the lateral veins the 'cristarque' is in direct contact with the sclerenchyma and corresponds to the endodermis. The 'cristarque' is found also in the petiole and axis.

§ 8. Structure of the Margin of the Leaf[2]. The peculiarities in the structure of the margin of the leaf may be used especially for the purposes of specific diagnosis, more rarely (see Berberideae, pp. 45, 820) for generic diagnosis. The margin of the leaf is distinguished either by a stronger development of the leaf-tissue or (very commonly) by the considerable size of its epidermal cells or by the development of a hypoderm, which is differentiated either as collenchyma or resembles hard bast (**marginal bast**); in the latter case the hypoderm often enters into connexion with the marginal vascular bundles. Marginal bast has been observed, for example, in certain Berberideae, Frankeniaceae, Ilicineae, Melastomaceae, Vacciniaceae, Ericaceae and Myrsineae.

§ 9. Spicular Cells (*including similar elements occurring in the axis*). The presence of spicular cells (i.e. mechanical cells having a parenchymatous or prosenchymatous (fibrous) shape) in the mesophyll is a widely distributed feature, which is in general only of value for specific diagnosis. In most cases the spicular cells arise from cells of the mesophyll and only very rarely from epidermal cells. The latter applies to the spicular cells, found in certain species of *Capparis*; the greater part of the body of these elements is situated in the mesophyll, but the upper part of each spicular cell is wedged in between the epidermal cells or even projects beyond the level of the epidermis like a hair (Fig. 18, *C*, p. 68).

The differentiation of the spicular cells varies very considerably. In the simplest case they are ordinary stone-cells, those situated in the palisade-tissue being elongated like rod-cells; in other cases they give off branches in all directions or are elongated in a columnar manner, spicular cells of the latter type often extending from one epidermis to the other and even branching beneath the epidermis. In other cases again they are fibrous and then generally branch off from the sclerenchymatous sheaths of the veins; such spicular cells traverse the mesophyll in various ways (their course often being very irregular) and frequently form a complete plexus beneath the epidermis on the two sides of the leaf. The spicular cells, and especially those which are differentiated like fibres, for the most part have thick walls; in certain Euphorbiaceae the walls show well-marked stratification. The following are **special forms of spicular cells**: (*a*) the fibre-like spicular cells of *Pelliciera* (Ternstroemiaceae), which have pointed ends and run parallel to one another in the mesophyll in two planes, parallel to the surface of the leaf; (*b*) the spicular cells of *Hemiboea Henryi*, Clarke (Gesneraceae), which resemble rod-cells, are placed parallel to the surface of the leaf and are covered by a group of upper epidermal cells of relatively small size; (*c*) the sac-like spicular cells of *Linociera glomerata*, Pohl (Oleaceae),

[1] See Van Tieghem, Cristarque, &c., Bull. Mus. d'hist. nat., 1902, p. 266, and the remaining papers by this author, cited in the list of literature for the Ochnaceae, p. 869.

[2] Hintz, Mechan. Bau d. Blattrandes, Nova Acta Acad. Leopold.-Carol., liv, 1890, p. 97 and tab. v–vii.

which frequently fork and have wide lumina and relatively thin walls, the latter being wrinkled owing to the presence of transverse folds; (*d*) the branched spicular cells of *Heptacyclum Zenkeri*, Engl. (Menispermaceae), which are likewise sac-shaped and have wide lumina and relatively thin walls; (*e*) the bundles of sclerenchymatous fibres running in a subepidermal position in the leaf of the Theophrasteae and *Polygonum equisetiforme*; (*f*) the groups of sclerenchymatous fibres, developed beneath the hypoderm of the leaf in the *Eryngias* having a Monocotyledonous habit; (*g*) the sclerenchymatous fibres of certain Sapotaceae and Penaeaceae (*Fig. 175, p. 723*), which are provided with spiral thickening; (*h*) the parenchymatous or prosenchymatous spicular cells of certain Mimoseae (Fig. 65, *A*, *B*, p. 295), Melastomaceae (Fig. 79, *E*, *F*, p. 362), Compositae and Euphorbiaceae (Fig. 180, p. 748), which occur in connexion with simple trichomes or shaggy hairs of complicated structure and form a foot to the hair (see also § 33); (*i*) the spicular fibres penetrating into the glandular shaggy hairs of *Begonia imperialis*; (*j*) the sclerenchymatous rod-cells of certain Melastomaceae, which lie in the parenchyma, accompanying the larger veins, and are placed parallel to the surface of the leaf; (*k*) the branched spicular cells of *Cynometra* (Caesalpinieae), which are filled with siliceous contents; (*l*) the branched spicular cells of certain *Begonias* (Fig. 87, *B*, p. 400), which have wide lumina and mostly include solitary crystals of oxalate of lime; (*m*) the spicular cells which have been observed in many Loranthaceae; these elements are mostly branched, and their walls are thickened to such an extent that only one or more peripheral portions of the lumina remain, these being filled by solitary crystals of oxalate of lime (crystal-sclerenchyma, Fig. 177, p. 728); (*n*) lastly, the branched spicular cells, which are differentiated as 'internal hairs.' In the Nymphaeaceae (Fig. 11, *A*, p. 47) the elements last named (the occurrence of which is indicated in the following enumeration by the insertion of a *) are frequently distinguished by being encrusted with small crystals of oxalate of lime; in *Rhizophora* (Fig. 74, p. 340) and *Nymphaea* they sometimes have the shape of an H.

The special forms of spicular cells are by no means characteristic of certain Orders or genera. In Orders like the Capparideae or Ternstroemiaceae, or genera like *Linociera* (Oleaceae) or *Mouriria* and *Memecylon* (Melastomaceae), in which spicular cells are of frequent occurrence, different forms of these elements are found from species to species. We may add that spicular cells, which traverse the leaf in a vertical direction, may give rise to transparent dots in the same.

With the spicular cells we may class the 'cristarque'-cells (see the end of § 7, p. 1090), observed in the mesophyll of certain Ochnaceae and Lineae, and the peculiar groups or rows of cells, which occur in the mesophyll and cortical parenchyma of certain Convolvulaceae (Fig. 128, p. 564); the function of these groups of cells is still quite unknown.

Spicular cells have been observed **in the mesophyll** in certain species of the following Orders and genera respectively: Dilleniaceae, Magnoliaceae, *Trochodendraceae, Anonaceae, *Menispermaceae, *Nymphaeaceae, Capparideae (Fig. 18, p. 68), Bixineae, Polygaleae, Vochysiaceae, Frankeniaceae, Tamariscineae, Guttiferae, *Ternstroemiaceae (Fig. 29, p. 129), *Microsemma*, Dipterocarpeae, Malvaceae, Rhaptopetalaceae, Lineae, Humiriaceae, Malpighiaceae, Zygophylleae, Rutaceae, Simarubaceae, Ochnaceae sens. str., Luxemburgiaceae, Meliaceae, Chailletiaceae, Olacineae, Ilicineae, Celastrineae, Hippocrateaceae, Rhamneae, Sapindaceae, Hippocastanaceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae, Saxifragaceae, Hamamelideae, *Ostrearia*, Bruniaceae, *Rhizophoraceae (Fig. 74, p. 340), Combretaceae, Myrtaceae sens. str., Lecythidaceae, Melastomaceae, Lythrarieae, Samydaceae, Passifloraceae, Begoniaceae (Fig. 87, p. 400), Datisceae, Cornaceae (Fig. 99, p. 435), Rubiaceae, Candolleaceae, *Goodeniaceae, Vacciniaceae, Ericaceae, Epacrideae, *Plumbagineae, Myrsineae, Sapotaceae, Ebenaceae, Styraceae, Oleaceae (Fig. 119, p. 523), Apocynaceae, Asclepiadeae, *Loganiaceae, *Gentianeae, Bora-

gineae, Convolvulaceae, Solanaceae (not typical), Gesneraceae, Bignoniaceae, Selagineae, Polygoneae, *Myristicaceae, Monimiaceae, Laurineae, *Proteaceae (Fig. 173, p. 713), Thymelaeaceae, Penaeaceae (Fig. 175, p. 723), Loranthaceae (Fig. 177, p. 728), Euphorbiaceae (Fig. 180, p. 748), Moraceae, *Didymeles*.

In connexion with this enumeration we may mention that extensive **groups of sclerosed or at least thick-walled tissue occur in the mesophyll** (especially in the spongy tissue) in certain Magnoliaceae, Menispermaceae, Berberideae, Capparideae, Polygaleae, Tamariscineae, Guttiferae, Lineae, Celastrineae, Sapindaceae, Connaraceae, Melastomaceae, Vacciniaceae, Styraceae, Orobanchaceae, Piperaceae, and Chloranthaceae.

Spicular cells, similar to those found in the mesophyll, occur also in the pith, primary cortex, and (more rarely) bast **of the axis**, and may therefore be discussed here, at once. Branched spicular cells, some of which are differentiated as internal hairs, are present in the axis in certain species of the Magnoliaceae, Trochodendraceae, Nymphaeaceae, Ternstroemiaceae, *Lophira*, Rutaceae, Meliaceae, Hippocrateaceae, Rhizophoraceae, Lythrarieae, Datisceae, Primulaceae, Loganiaceae, Gentianeae, Chenopodiaceae, and Gomortegaceae; as a rule their presence corresponds to the occurrence of spicular cells in the mesophyll, and this applies also to the crystal-sclerenchyma found in the cortex of certain Loranthaceae. It is an interesting fact that the sclerenchymatous fibres, which are found running irregularly in the mesophyll in many species, do not occur in the cortex in these same species, such elements being extraordinarily rare in this part of the plant; it is only in the mesophyll, of course, that they are of functional importance. It remains to mention the following **special types of spicular cells observed in the axis**: (*a*) the crystal-sclerenchyma, found in certain genera of the Schizandreae (Fig. 4, p. 29) and Rubiaceae, as well as in the Combretaceous genus *Macropteranthes*; the crystal-sclerenchyma in these forms develops in the same way as in the Loranthaceae (see above), but the shape of the elements is different and subject to variation; (*b*) the elongated sclerenchymatous cells, occurring in the pith in certain Dilleniaceae, Combretaceae, and Loganiaceae; (*c*) the sclerenchymatous fibres, which run in various directions in the primary cortex of species of *Prunus* (Rosaceae[1]); (*d*) the well-known spicular cells, found in the bast of the *Cinchona*-bark, and the elements of a similar shape, occurring in *Ancistrocladus* and *Styrax* (Styraceae); (*e*) the long sclerenchymatous cells present in certain Apocynaceae, these elements having thick walls and a tuberculate surface; (*f*) the bast-fibres of the Quebracho-bark (Apocynaceae), which are completely enveloped by a sheath composed of a single layer of cells, each containing a solitary crystal. For the occurrence of ordinary stone-cells, groups of stone-cells, 'cristarque'-cells, and groups of sclerenchymatous fibres in the pith or primary cortex, cf. §§ 40 and 51; see also § 53.

§ 10. Enlarged Terminal Tracheides[2]. Enlarged terminal tracheides (i.e. cells, which have wide lumina and are either spirally thickened or have thick pitted walls) are in general only of specific value; they are found at the ends of the vascular bundles of the veins, and function as water-reservoirs.

They have been observed in certain Capparideae (Fig. 18, p. 68), Polygaleae, Tamariscineae, Hypericineae, Guttiferae, Ternstroemiaceae, Geraniaceae, Rutaceae, Olacineae, Celastrineae, Papilionaceae, Mimoseae, Rosaceae, Rhizophoraceae, Combretaceae, Lythrarieae, Compositae, Salvadoraceae, Gentianeae-Menyanthoideae, Loranthaceae, Santalaceae, Euphorbiaceae and Balanopseae[3].

§ 11. Storage-Tracheides in the Ground Tissue of the Leaf and Axis. The storage-tracheides found in the ground tissue have the same physiological function and the same systematic value as the terminal tracheides. In some cases entire groups of tissue are composed of such elements, e.g. in the axis of *Oudneya africana*, R. Br. (Cruciferae) and in the root of certain species of *Drosera*, in

[1] Möller, Rindenanatomie, p. 369 et seq.

[2] Heinricher, in Bot. Centralbl., 1885, iii, p. 25.

[3] The above enumeration is but an incomplete one, owing to the fact that the term 'enlarged terminal tracheides' has not always been interpreted in the same sense by different authors.

which the outer cortical tissue is formed by cells with reticulate or spiral thickening; in this relation we may once more recall the reticulate thickening of the palisade-tissue of *Clusia rosea* and other features, already discussed in § 6. In the majority of cases the storage-tracheides are more or less isolated, occurring either in the middle of the ground tissue or in connexion with the vascular system or the secretory organs.

Special storage-tracheides, in the form of narrow sac-shaped elements with spiral thickening, adjoin the ends of the veins in *Vochysia rufa*, Mart., and penetrate from these points as far as the epidermis of the leaf; short spiral tracheides are found in the pith of *Anacampseros* (Portulaceae); isolated spiral and annular tracheae are present in the pith of *Impatiens* (Geraniaceae). Wide sac-shaped spiral tracheides (occasionally side by side with sclerenchyma) accompany the secretory canals of *Calophyllum* (Guttiferae, Fig. 27, *D*, p. 122), which run freely in the mesophyll; a similar relation to secretory cavities is shown by the spiral tracheides, which branch off from the vascular bundles of the veins in *Caraipa* (Ternstroemiaceae, Fig. 29, *E*, p. 129) and *Haplophyllum* (Rutaceae). The spirally thickened spicular fibres, running irregularly in the mesophyll in certain Penaeaceae (Fig. 175, p. 723), and the spirally thickened spicular fibres of certain species of *Micropholis* (Sapotaceae) have already been briefly referred to in § 9. The spiral fibres of *Micropholis* are closely related to the tubular spiral tracheides, developed in the mesophyll of *Ochthocosmos* (Lineae), *Aciotis annua*, Tr. (Melastomaceae), *Macrocnemum* and *Pentagonia* (Rubiaceae), the Nepenthaceae (Fig. 164, *A*, *B*, p. 678) and *Pogonophora* (Euphorbiaceae), as well as in the pith and cortex of the Nepenthaceae, and in the palisade-tissue, found in the primary cortex of species of *Arthrocnemum* and *Salicornia* (Chenopodiaceae). Spiral tracheides of exactly the same type accompany the vascular bundles of the veins in *Sommera* (Rubiaceae), while transitional forms between such tracheides and ordinary sclerenchymatous fibres are found in the same position in *Emmotum* (Olacineae) and *Chomelia* (Rubiaceae). It remains to mention the systems of tracheides, running freely in the mesophyll and independently of the vascular bundles of the veins in *Petalonyx Thurberi* (Loaseae), the Opilieae (Olacineae), *Nuytsia* and species of *Loranthus* (Loranthaceae), species of *Osyris*, *Quinchamalium*, *Thesium*, and *Myzodendron* (Santalaceae), and the rows of tracheides, situated on either side of, and parallel to, the cortical vascular bundles in the axis of the Casuarineae (Fig. 186, p. 788). Regarding the nature of the storage-tracheides found in *Boscia* (Capparideae) and species of *Bellucia*, *Henriettea*, and *Sonerila* (Melastomaceae), see under the Orders named.

II. Structure of the Petiole.

§ 12. The Structure of the Petiole was already employed for systematic purposes[1] at an early date, but its systematic value has frequently been overestimated. At the outset it was to be presumed that **the number of vascular bundles in the petiole and** to some extent also **their arrangement** (including the occurrence of medullary and cortical vascular bundles) would depend on the dimensions of the leaf; it has moreover been shown that as a general rule the vascular bundles of the petiole are isolated in herbaceous species and fused in various ways in woody species.

[1] Cas. de Candolle, in Mém. Soc. de phys. et d'hist. nat. de Genève, t. xxvi, 2e part., 1879, p. 427 and pl. 1, 2; Plitt, Blattstiel d. Dicot., Diss., Marburg, 1886, 52 pp. and 1 Tab.; Petit, in Mém. Soc. sc. phys. et nat. de Bordeaux, sér. 3, t. iii, 1887, p. 218, and 6 pl., and in Act. Soc. Linn. de Bordeaux, t. xliii, 1889, p. 11, see also in Comptes rendus, t. civ, 1886, and Ann. sc. nat., sér. 7, t. vi, 1887, p. 342; Lignier, in Bull. Soc. Linn. de Normandie, 1888, p. 81, and Comptes rendus, t. cvii, 1888, p. 402; Acqua, in [Ann. Ist. bot. di Roma, Vol. iii, fasc. 1, 1887, 35 pp.] and Malpighia, i, 1887, p. 277; Chatin, in Bull. Soc. bot. de France, 1897, p. 464, and 1898, pp. 137, 145, 165, 241, and 310; Bouygues, Various papers in Act. Soc. Linn. Bordeaux, lvi, lvii, and lviii, 1901–3, especially the 'Thèse, Paris, 1902 (Cert. formes vasc. anomales du pétiole des Dicotyléd.)' contained in t. lvii; Col, in Ann. sc. nat., sér. 8, t. xx, 1904, p. 1, and Comptes rendus Acad. Paris, cxxxvi, 1903, p. 516; finally, Van Tieghem's numerous systematic papers, in which the structure of the petiole is often profitably employed for systematic purposes.

In most cases the structural features just mentioned can be used only for purposes of specific diagnosis, but they are occasionally of greater systematic value. Thus, a transverse section through the apex of the petiole of any of the Dipterocarpeae shows a closed ring of wood and bast, surrounding a tissue which resembles a pith and encloses a vascular system of varied structure; again, the genera of the Dipterocarpeae, the subdivisions of the Lecythidaceae, the genera of the Salicineae, the genera and generic groups of the Cupuliferae, can all be distinguished with the help of the structure of their petiole.

In an investigation of the structure of the petiole it is of course requisite that analogous portions be compared with one another (unless the entire course of the vascular system is followed up,—an arduous task, which generally does not repay the amount of labour involved and cannot always be undertaken owing to lack of the necessary material), since the appearance of the transverse section may vary at different points in the course of the petiole. Petit's investigations in particular have helped to show that the most suitable points at which to examine the petiole are its base and especially its apex; we may follow Petit in describing the transverse sections taken through these particular regions respectively as the 'initial' ('initiale') and 'characteristic' ('caractéristique'). A point of special importance appears to be the number of vascular bundles [1], passing out from the stem into the leaf or petiole, as the case may be.

An anomalous differentiation of the fibrovascular system of the petiole is connected with the occurrence of what are called 'rayed bundles' ('Faisceaux rayonnés') and 'true concentric or hemiconcentric bundles' ('Faisceaux concentriques ou hémiconcentriques vrais')[2]. The first anomaly has been recorded in the Cruciferae [3]. A transverse section through the petiole in this Order shows a tissue-system, which has a lobed outline and is composed of radially arranged vascular bundles with intervening tissue consisting of small thin-walled cells, the whole being surrounded by a tissue made up of large cells with thin walls; the whole of the lobed tissue-system arises from a single procambial strand. In the case of the second anomaly, the petiolar tissue contains several vascular bundles, which are completely or incompletely concentric (with a central xylem-mass), and in most cases are provided with an endodermis, distinguished by the presence of Caspary's dots; in other words, we have a kind of polystely (cf. § 55).

The second anomaly has been observed in certain Rosaceae, Saxifragaceae, Hamamelideae, Halorageae (*Gunnera* pro parte), Valerianeae, Campanulaceae, Primulaceae, Gesneraceae, Acanthaceae and Labiatae.

The **pulvini** ('Schwellpolster'), which occur at the bases of the petioles or of the stalks of the individual pinnae, for example in many Menispermaceae, Leguminosae, Oxalideae and Zygophylleae, show few noteworthy points of difference in structure [4].

On the other hand, from the systematic point of view, it remains to consider the sclerenchymatous tissue, accompanying the fibrovascular system on its outer side, and perhaps also the pith-like ground tissue enclosed by the vascular system. The sclerenchyma, accompanying the vascular tissue, shows features similar to those exhibited by the sclerenchyma found in the larger veins. The outer ground tissue, which forms a continuation of the primary cortex of the stem, commonly repeats the structural features presented by the latter, while the inner ground tissue shows the same type of structure as the pith.

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[1] See also especially Chatin, ll. cc.
[3] Bouygues, loc. cit.

[2] Similar types of structure, shown by the fibrovascular system of the petiole, are termed 'Pseudo-faisceaux rayonnés' by Bouygues; they differ from the 'Faisceaux rayonnés' in their course of development.

[4] See Haberlandt, Physiol. Pflanzenanat., 1904, p. 499, and the papers by Schwendener, Haberlandt, Möbius and Pantanelli there cited (under 11); also Preuss, Bezieh. zwischen dem anat. Bau u. der physiol. Funktion d. Blattstiele u. Gelenkpolster, Diss., Berlin, 1885, 38 pp.

III. Secretory and Excretory Receptacles.

§ 13. General Points about Secretory Receptacles[1]. The great systematic value of the secretory receptacles was recognized at an early date. In employing these elements for systematic purposes we have in the first place to determine their nature (secretory cells, secretory cell-fusions, secretory cavities, secretory canals), but, apart from this, their contents[2] and their position within the plant also come into consideration. All these features are of great importance; they are often characteristic of entire Orders or at least of tribes or genera, although in some cases they only serve to distinguish species.

As regards the occurrence of the secretory receptacles in the different parts of one and the same species, we may note at this point that in most cases the same types of secretory receptacles are present in all the vegetative and reproductive organs of the plant. We do, however, sometimes find that the secretory receptacles are confined to certain organs of the plant (such as stem, leaf, root or flower), or that different types of secretory receptacles are present in the different parts of the plant. Thus in the Hypericineae, for example, the secretory cavities of the leaf are replaced by secretory canals in the axis, and similarly in the Rutaceae the secretory cavities of the leaf give way to secretory cells in the bast of the axis. In the same way as different types of secretory organs may occur in one and the same species, various kinds of internal secretory organs may be found in different species or genera belonging to the same Order.

Apart from those secretory receptacles which are typically differentiated, attention should also be paid to the distribution of **tannin** in the ordinary cells of a tissue. Very striking features are afforded by the way in which the dry cortex or mesophyll is filled with reddish-brown phlobaphenes in herbarium-material of a certain species, genus or Order, while such substances are wanting in other species, &c.

The following is an enumeration of the Orders and genera in which **special internal secretory organs**[3] **have not hitherto been observed**: Ranunculaceae, Dilleniaceae ?, Berberideae, Sarraceniaceae, Cistineae, Tremandreae, Polygaleae ?, Frankeniaceae, Caryophylleae, Tamariscineae, *Lophira*, Rhaptopetalaceae ?, Lineae, Humiriaceae, Malpighiaceae ?, Ochnaceae incl. Luxemburgiaceae, Chailletiaceae ?, Octocnemaceae, Ilicineae, Cyrilleae, Pentaphylacaceae, Corynocarpaceae, Stackhousieae ?, Melianthaceae, Staphyleaceae, Sabiaceae, Coriarieae, Crossosomataceae, Droseraceae, *Ostrearia*, Bruniaceae, Halorageae, Rhizophoraceae, Melastomaceae (apart from tannin-idioblasts), Onagrarieae, Loaseae, Turneraceae ? (apart from tannin-cells), Cucurbitaceae ?, Begoniaceae ?, Datisceae, Calycereae, Candolleaceae ?, Vacciniaceae, Ericaceae, Epacrideae, Diapensiaceae, Lennoaceae, Plumbagineae, Ebenaceae, Oleaceae, Salvadoraceae, Loganiaceae, *Desfontainea*, *Plocosperma*, Gentianeae ? (apart from secretion contained in intercellular spaces), Polemoniaceae (apart from secretion contained in intercellular spaces), Hydrophyllaceae, Boragineae, Nolaneae, Solanaceae ?, *Retzia*, Scrophularineae (apart from tannin-idioblasts), Orobanchaceae, Lentibularieae, Columelliaceae, Bignoniaceae, Pedalineae, Acanthaceae ?, *Zombiana*, Selagineae, Plantagineae, Illecebraceae, Amarantaceae, Chenopodiaceae, Phytolaccaceae, Batideae, Nepenthaceae, Thymelaeaceae, Penaeaceae, *Geissoloma*, Elaeagnaceae, Santalaceae, *Myzodendron*, *Champereia*, *Grubbia*, Balano-

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[1] The term 'secretory receptacles' is here understood to comprise cells, cell-fusions, or intercellular spaces, which are filled with a secretion.

[2] Mangin, Classification des mucilages, Bull. Soc. bot. de France, 1894, p. xl; Tschirch, Die Harze u. die Harzbehälter, Leipzig, 1900; Molisch, Milchsaft u. Schleimsaft, Jena, 1901.

[3] In this enumeration gelatinized epidermal cells and mesophyll-cells provided with local swellings (for these cf. §§ 2 and 6) are not taken into consideration; ordinary tanniniferous cells, that is to say cells, which are not distinguished by their shape or size, and are filled with brown contents in herbarium-material, are likewise not taken into account.

phoreae, Daphniphyllaceae, Balanopseae, Thelygoneae, Platanaceae, Juglandeae, Myricaceae ?, Casuarineae, Cupuliferae, Salicineae, Lacistemaceae, Empetraceae, Ceratophylleae (apart from tannin-cells).

§ 14. SECRETORY CELLS[1]. This term is taken to include all such cells as contain secretion and appear as idioblasts, owing to their shape or their contents, or both shape and contents, with the exception of mucilage-cells and laticiferous cells, which will be discussed separately in §§ 15 and 20.

The shape of the secretory cells varies. In some cases they appear as distinct idioblasts, which are spherical, ellipsoidal, branched or sac-shaped, and vary in length, while commonly giving rise to pellucid dots in the leaf; in other cases, however, they differ but little from the neighbouring cells or are distinguished merely by their contents. The sac-shaped secretory cells are frequently arranged in rows, while the spherical secretory cells of the leaf are often replaced by elongated cells in the axis (especially in the bast) of the same species. The contents are resinous, oily, gummy, or resemble latex or caoutchouc; in other cases they are tanniniferous, and are then coloured brown in herbarium-material. The cell-wall is occasionally suberized or provided with a suberized lamella.

The detailed structure of the secretory cells of certain Magnoliaceae, Canellaceae, Aristolochiaceae, Piperaceae and Laurineae, which are filled with a resinous or oily secretion, is specially noteworthy; their secretory contents are enveloped by a thin-walled sheath ('pouch'), which is formed from the wall of the vacuole by a change in its substance, and is connected with the cell-wall by means of a stalk ('basin' or 'funnel'), which constitutes a thickening of the membrane[2]. These secretory cells are doubtless very closely related to the (paired) cystospheres of certain Begoniaceae[3], which are dealt with in § 28. The secretory cells of *Pogostemon Patchouli* (Labiatae), which are differentiated as true **internal glandular hairs**, may also receive special notice at this point; they are provided with a short stalk, mostly composed of two or three low cells having suberized walls, and project into the intercellular spaces; the abundant secretion accumulates chiefly between the cuticle, which is raised like a bladder, and the cellulose-membrane.

As regards the **position of the secretory cells in the different tissue-systems** it may be pointed out that the occurrence of these elements in the epidermis (especially in the leaf) has proved to be of systematic value. It must, however, be borne in mind that secretory cells, which are apparently situated in the epidermis, but belong to the subepidermal tissue (having pushed their way secondarily between the epidermal cells by a process of sliding growth), can in some cases be distinguished with certainty from true epidermal secretory cells only by a study of their course of development[4].

Secretory cells sometimes characterize entire Orders, these being indicated by a * in the following synopsis; in other cases they are at least distinctive of genera or species.

I. **Secretory cells, of various shapes, with resinous (oily), latex-like or other contents** (apart from very much elongated secretory cells, filled with similar contents, which are enumerated under II), have been observed in the following Orders and genera respectively: *Calycanthaceae (resin-cells, rounded in the leaf), *Magnoliaceae (resin-cells, rounded in the leaf and occasionally also in the wood), Trochodendraceae (branched and elongated resin-cells), *Lactoridaceae (resin-cells, rounded in the leaf), *Anonaceae (resin-cells, rounded in the leaf and occasionally also in the wood), Menispermaceae (sac-shaped secretory cells of varied length and

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[1] De Bary, Vergl. Anat., 1877, p. 152; Zacharias, in Bot. Zeit., 1879, pp. 617 and 633; Biermann, Ölzellen, Diss., Bern, 1898, also in Archiv d. Pharm., 1898, p. 74.

[2] Berthold, Protoplasmamechanik, Leipzig, 1886, p. 25; Haberlandt, Physiol. Pflanzenanat., 1904, p. 462; R. Müller, in Ber. deutsch. bot. Gesellsch., 1905, p. 292.

[3] Cf. the detailed statements on this point in Fellerer, Beitr. z. Anat. u. Syst. d. Begoniaceae, Diss., München, 1892, p. 41 et seq. and Tab. I; this paper also deals with the course of development of these structures.

[4] See R. Müller, in Ber. deutsch. bot. Gesellsch., 1905, p. 292.

provided with brown, gummy or other contents in the leaf and axis), *Nymphaeaceae (isodiametric or elongated laticiferous sacs, occasionally arranged in rows), Papaveraceae (laticiferous sacs, as in the previous case), Fumariaceae (sac-shaped cells, often very long and likewise arranged in rows), Capparideae (Cleomeae with secretory cells in the neighbourhood of the vascular bundles of the veins), *Canellaceae (resin-cells, rounded in the leaf), Bixineae (sac-shaped and branched resin-cells), Polygaleae (oil-cells only in '*Radix Senegae*'), Elatineae (resin-cells), Ternstroemiaceae, *Ancistrocladus* (cortex), Tiliaceae (rounded resin-cells), Lineae (pith and cortex of *Erythroxylon*), Geraniaceae (*rounded secretory cells*), Rutaceae (*resin-cells*, only in the axis), Simarubaceae (resin-cells, in part only in the axis), *Meliaceae (spherical to sac-shaped or branched resin-cells, occasionally arranged in rows), Olacineae, Sapindaceae (often laticiferous, isolated and of varied shape or arranged in rows, very widely distributed), Hippocastanaceae (resin-cells, rounded in the leaf), *Aceraceae (with latex-like or other contents, probably always present in the bast of the veins, but also occurring freely in the mesophyll and in the axis), Connaraceae, *Papilionaceae, Caesalpinieae, Mimoseae (various types, occasionally with gelatinized* membranes), Saxifragaceae (elongated secretory cells only in the pericycle of *Abrophyllum*), Hamamelideae (Altingieae, not differentiated as idioblasts), *Myrothamnus* (spherical resin-cells), Myrtaceae-Lecythidaceae ? (*Napoleonea*), Samydaceae (very rare, in *Casearia*, here side by side with secretory cavities), Cornaceae (only in the veins of the leaves of species of *Nyssa*), Rubiaceae (resin-cells), Valerianeae (*only in the root*), Compositae, Candolleaceae (indistinctly differentiated), Plumbagineae (cells in the stem and root filled with plumbagin), Primulaceae (red contents, in part only in the root), Myrsineae (red contents), *Sapotaceae (laticiferous, the latex occasionally containing crystal-sand ; elongated cells, sometimes arranged in rows), *Brachynema* (blood-red contents in rows of cells, situated *in the primary cortex*), Apocynaceae (rare, in the cortex ; also a layer of secretory cells beneath the palisade-tissue in certain species), Asclepiadeae (*Solenostemma*), Convolvulaceae (frequently laticiferous, solitary secretory cells and rows of secretory cells, the latter almost of general distribution), *Cuscuteae (resin-cells), Verbenaceae (*Congea* and *Symphorema*), Labiatae (sac-shaped resin-cells ; in *Pogostemon* in the form of typical internal glandular hairs), Polygonaceae ? (probably merely secretory cavities), *Aristolochiaceae (rounded resin-cells, of frequent occurrence in the epidermis of the leaf, occasionally as basal cells of the hairs, not always present in the leaf), *Piperaceae (rounded resin-cells), *Chloranthaceae (as in the previous case), *Myristicaceae (as in the Piperaceae, occasionally with gelatinized membranes), *Monimiaceae (as in the Piperaceae), *Laurineae (as in the Piperaceae, occasionally also in the wood), *Hernandiaceae (as in the Piperaceae), *Gomortegaceae (*as in the Piperaceae*), Euphorbiaceae (*rows* of laticiferous sacs, and oil-cells, the latter occasionally differentiated like hairs, Fig. 180, p. 748), Buxaceae (not very typically differentiated), Moraceae (spherical secretory cells), Myricaceae (rare). We may add that the rows of laticiferous sacs found in certain Sapotaceae and Convolvulaceae show transitions to laticiferous vessels (see § 21).

We may also mention the following elements at this point : (*a*) cells, containing myrosin (**myrosin-cells** [1]) and differing more or less from the neighbouring cells, probably occur in all Cruciferae, and have been recorded also in certain Capparideae, Resedaceae, and Geraniaceae, as well as in *Bretschneidera*, *Moringa*, and the genus *Scorodophloeus* (Caesalpinieae) ; (*b*) elongated spicular cells, some of which at least are filled with contents, are found in the pith of certain Dilleniaceae and species of *Combretum* ; (*c*) peculiar strands of secretory cells, which appear as ribs even to the naked eye, occur in the axis of *Stocksia* (Sapindaceae), and similar strands of secretory cells, in which the inner cells subsequently become resorbed and replaced by a secretory canal, are present in *Prosopanche* (Cytinaceae) ; lastly (*d*) groups of glandular cells have been observed in the mesophyll in *Heterophyllaea* (Rubiaceae).

II. **Elongated secretory sacs** have been observed in the pith, bast, or pericycle of the stem, and occasionally also in the larger veins of the leaf in certain members

[1] *In addition to the papers of Heinricher, Guignard, Spatzier, Radlkofer, &c.*, which are cited in the lists of literature belonging to the respective Orders, see especially *Hartwich*, Babimbirinde, Zeit. d. deutsch. Apothekerver., 1902, p. 339. In this paper sulphur-containing oils are stated to occur in certain members of the following Orders : Bombaceae (Malvaceae), Caesalpinieae, Capparideae, Caricaceae (Passifloraceae), Cruciferae, Euphorbiaceae, Labiatae, Limnanthaceae (Geraniaceae), Meliaceae, Moringeae, Phytolaccaceae, Resedaceae, Rubiaceae, Tropaeolaceae (Geraniaceae), Umbelliferae.

of the Orders enumerated below; most of these elements resemble the well-known tannin-sacs, found in the pith of the elder, but in some cases they are shorter, and are then often arranged in rows; their contents are mostly brown and tanniniferous or latex-like or resinous. The Orders in question are: Trochodendraceae, Menispermaceae, Berberideae?[1], Hippocrateaceae, Anacardiaceae, Connaraceae, Papilionaceae (very widely distributed, Fig. 56, p. 259), Mimoseae (with diverse contents), Chrysobalaneae, Crassulaceae, Lecythidaceae, Passifloraceae, Caprifoliaceae, Rubiaceae (in part resembling bast-fibres), Dipsaceae, Compositae, Polygonaceae, Myristicaceae, Monimiaceae, and Euphorbiaceae. In certain Compositae (*Gazania*, *Atractylis*, and *Carlina*) one finds transitional forms between the elements in question and laticiferous vessels; in the group Compositae-Cynaroideae the secretory sacs and secretory canals are vicarious in their occurrence in one and the same species (for details, see under Compositae, pp. 959, 960). See also § 20, p. 1103 under 'secretory organs resembling laticiferous cells.'

Similar long secretory sacs with brown contents have been observed in the epidermis of the leaf (cf. § 2) in certain Violarieae, Geraniaceae, Saxifragaceae, Crassulaceae and Euphorbiaceae, and in the uppermost layers of the mesophyll in certain Crassulaceae and Ficoideae, while sac-shaped mucilage-cells occur in the epidermis of the leaf of *Tropaeolum* (Geraniaceae).

Tannin-idioblasts, the shape of which is similar to or differs from that of the elements previously discussed, are found in the leaf (here commonly in the form of enlarged cells of the palisade-tissue) or axis, in representatives of the following Orders: Violarieae (mesophyll), Zygophylleae (mesophyll), Geraniaceae (mesophyll), Chailletiaceae (mesophyll), Celastrineae (mesophyll), Hippocrateaceae (mesophyll and bast of the axis), Stackhousieae (leaf and axis), Rhamneae (mesophyll), Didiereae (leaf and axis), Papilionaceae (leaf and axis), Melastomaceae (leaf), Turneraceae (scattered groups of tannin-cells in the leaf, idioblasts in the cortex), Passifloraceae (mesophyll), Rubiaceae (mesophyll and bast), Monotropeae (axis), Gentianeae (rhizome), Solanaceae (root), Scrophularineae (mesophyll), Nyctagineae (enlarged cells in the epidermis of the leaf), Polygonaceae (branched cells in the cortex), Aristolochiaceae (mesophyll), Piperaceae (mesophyll), Euphorbiaceae (leaf and axis), Moraceae (mesophyll), Ceratophylleae (cortex and mesophyll).

§ 15. MUCILAGE-CELLS. The gelatinization of epidermal and hypodermal cells has already been discussed in § 2 (p. 1074), and at this point I propose to consider only those mucilage-cells which occur outside the integumental tissue. The mucilage contained in these elements is in almost all cases membrane-mucilage, which arises by the gelatinization either of the entire cell-wall or only of a part of it. The mucilage appears to be derived from the contents only in the Ampelideae, Onagrarieae, and Rubiaceae, in which the receptacles in question can be interpreted as incompletely differentiated raphide-sacs (i.e. without raphides); the much-discussed mucilage of the Cacteae is probably membrane-mucilage.

Mucilage-cells have been demonstrated **in the tissue of the leaf** in certain species of the following Orders and genera: Magnoliaceae, Anonaceae, Capparideae ?, Resedaceae, Bixineae, Portulaceae, Ternstroemiaceae, *Strasburgeria*, Dipterocarpeae (also cells having a gelatinized membrane and containing a solitary crystal), Chlaenaceae, Malvaceae, Sterculiaceae, Zygophylleae, Simarubaceae, *Euthemis*, Burseraceae, Meliaceae, Olacineae, Hippocrateaceae, Rhamneae, Ampelideae, *Didierea*, Aceraceae, Connaraceae ?, Papilionaceae, Caesalpinieae, Rosaceae, Rhizophoraceae (Fig. 74, p. 340), Melastomaceae, Lythrarieae, Onagrarieae, Rubiaceae, Apocynaceae, Gentianeae, Acanthaceae, Basellaceae, Phytolaccaceae, Laurineae (very widely distributed, absent in the related Monimiaceae), Hernandiaceae, *Gonystylus*, *Octolepis*, Ulmaceae, and Moraceae. Regarding gelatinization of the spongy tissue and peculiar thickenings of the cells of the mesophyll, which are restricted to certain parts of the cell-wall and have a mucilaginous appearance, see § 6, p. 1088.

Mucilage-cells are present **in the axis** (pith, bast, or primary cortex) in certain species of the following Orders or genera: Schizandreae, species of *Tovaria* (?), Resedaceae, Violarieae, Bixineae, Vochysiaceae, Portulaceae, *Strasburgeria*, Dipterocarpeae, *Monotes*, Chlaenaceae, Malvaceae, Sterculiaceae, Tiliaceae, Simarubaceae, *Euthemis*, Burseraceae, Chailletiaceae, Pentaphylacaceae, Rhamneae, Ampelidaceae,

[1] Holm has lately described 'secretory ducts' in *Caulophyllum thalictroides*, Michx. (see Merck's Report xvi, 1907, pp. 94-6.)

Didiereae, Staphyleaceae, Papilionaceae, Rosaceae, Saxifragaceae, Cacteae, Apocynaceae, Basellaceae, Laurineae, Thymelaeaceae (*Gonystylus*, *Octolepis*), Euphorbiaceae, Ulmaceae.

§ 16. MUCILAGE-CAVITIES. Mucilage-cavities generally arise from groups of gelatinized cells, and it is frequently impossible to draw a sharp limit between the former and the latter; similarly, one finds transitions between mucilage-cavities and mucilage-canals. It remains doubtful whether the mucilage-cavities, which are situated above the xylem in the veins of certain species of *Terminalia* (Combretaceae) and are provided with an epithelium, are schizogenous in origin.

Mucilage-cavities have been observed in certain: Magnoliaceae? (veins of the leaf), Dipterocarpeae (primary cortex, petiole), *Monotes*, Chlaenaceae, Malvaceae (pith, cortex, petiole), Triplochitonaceae (cortex, veins of the leaf), Sterculiaceae (as in the Malvaceae), Tiliaceae (as in the Malvaceae, the cavities sometimes resembling canals), Zygophylleae (cortex, the contents including crystals), Rutaceae (primary cortex; in the wood in *Evodia rutaecarpa*, Hook. f. et Th. and *Zanthoxylon Budrunga*, Wall.), Simarubaceae (pith, prim. cortex, petiole, and veins of the leaf), Olacineae (in the soft tissue of the axis of *Phytocrene*), Rhamneae (widely distributed), *Didierea* (prim. cortex), *Alluaudia* (prim. cortex), Anacardiaceae (prim. cortex), Moringeae (cortex), Connaraceae (prim. cortex), Papilionaceae (secondary cortex and pith), Caesalpinieae (gum-lacunae in the wood of *Burkea africana*)[1], Combretaceae (phloem of the axis and veins of the leaf), Apocynaceae (various tissues of the axis, also in the leaf), Asclepiadeae (cortex of the root), Euphorbiaceae (cortex, see § 15).

§ 17. MUCILAGE-CANALS. The mucilage-canals develop schizogenously or (as in most cases) lysigenously. The presence of a distinct epithelium in the mucilage-canals is no more an absolutely certain criterion of their schizogenous origin, than it is in the case of the secretory cavities and secretory canals, to be discussed in §§ 18 and 19. The mucilage-canals occur in the pith and primary cortex; in the older axes of certain Sterculiaceae and of the Papilionaceous genus *Herminiera* they are found in the wood. In some cases they are present also in the veins of the leaf.

The occurrence of mucilage-canals is confined to certain: Violarieae, Bixineae, Vochysiaceae, Guttiferae, Quiineae, Malvaceae, Sterculiaceae (sometimes in the wood), Olacineae, Rhamneae, Ampelidaceae, Moringeae, Papilionaceae (in the wood), Rosaceae, Combretaceae, Lecythidaceae, Cacteae, Piperaceae, Chloranthaceae, Laurineae (*Cassytha*), Loranthaceae, Moraceae and Urticeae.

§ 18. SECRETORY CAVITIES[2]. The term secretory cavity is here used to comprise intercellular secretory spaces, which are spherical or ellipsoidal in shape and have contents, which are not mucilaginous (see § 16), but in other respects vary in character (being resinous, oily, gummy, crystalline or brown and tanniniferous); the mode of development of the cavities (whether schizogenous, lysigenous or schizolysigenous) is left out of consideration. The secretory cavities often give rise to transparent dots in the leaf, or more rarely to what are called 'opaque' dots. They are not always equally abundant in the different parts of the leaf, and are occasionally confined to its margin. In the axis, they are generally found in the pith and primary cortex, and have hitherto been observed in the bast, only in *Casearia grandiflora* (Samydaceae) and a few species of *Eucalyptus* (Myrtaceae); in some cases, moreover, their place in the axis, and especially in the bast, is taken by secretory cells (e.g. in the Rutaceae) or secretory canals (e.g. in the Hypericineae). Conversely, secretory cavities sometimes also occur vicariously in place of secretory canals, this being the case in the secondary tissues of the vascular system in the axis of certain Com-

[1] See Perrot et Gérard, in Bull. Soc. bot. de France, Mém. 6, 1907.

[2] De Bary, Vergl. Anat., 1877 p. 210.

positae. As regards the systematic value of the secretory cavities, they mostly occur in all the species of a genus and occasionally even (in the cases indicated by a * in the enumeration below) in all the members of an Order, and are rarely (as in the genus *Couepia* of the Chrysobalaneae and the genus *Cuphea* of the Lythrarieae) characteristic of species only. The determination of the mode of origin of the secretory cavities invariably requires an investigation of their course of development. The presence of an epithelium, lining the fully developed cavity, is not in itself a conclusive proof of its schizogenous origin.

The following are **special forms of secretory cavities**: (*a*) the secretory cavities of certain Rhamneae and Papilionaceae (Fig. 57, *B*, p. 262), which are provided with a papillose epithelium; (*b*) the secretory cavities of *Polygonum Hydropiper*, L., which are enveloped by four epidermal cells; (*c*) the secretory cavities of certain Papilionaceae (Fig. 57, *C*, p. 262), Mimoseae and Euphorbiaceae, which are surrounded by 'bracket-cells,' and the open secretory cavities of certain Menispermaceae and Papilionaceae, which may be classed with the former; (*d*) the intramural glands of the Papilionaceous genus *Psoralea* (Fig. 57, *A*, p. 262), and the glands of similar structure, found at the margin of the leaf and in the leaf-teeth in certain species of *Symplocos* (Styraceae); (*e*) the secretory cavities of the Proteaceous genus *Franklandia* (Fig. 173, *C*, p. 713), which are traversed by rows of cells and, so far as their development is concerned, are no doubt related to the intramural glands; (*f*) the fused secretory sacs of certain Myrsineae, which arise from groups of cells, the peripheral walls of which remain intact; and (*g*) the albumen-containing glands, found in the Myrsineae; they probably develop after the manner of the intramural glands and recall the structure of the glands of *Franklandia* (see above). Secretory cavities have been observed in hairs or emergences in certain Rutaceae, Papilionaceae, Caesalpinieae, Myrtaceae, and Lythrarieae (cf. also § 34, under I, *a* and II).

In the secretory cavities of the Rutaceae and Myrtaceae, which occupy a superficial position, a special mechanism of a characteristic kind serving for the emission of the secretion has been demonstrated; for details on this point, see the Orders named, pp. 856 and 920.

Secretory cavities have been recorded in the following Orders and genera respectively: Menispermaceae (open secretory cavities), Bixineae, Polygaleae ?, *Hypericineae (resin-canals in the axis), Guttiferae, Ternstroemiaceae (all Bonnetieae excepting *Archytaea* and *Bonnetia*, Fig. 29, p. 129), Malvaceae, Triplochitonaceae (secretory cavities?), Malpighiaceae ? (*Aspidopterys*), Geraniaceae (with sphaerocrystalline contents), *Rutaceae (secretory cells common in the bast), Simarubaceae (in genera, which should rather be referred to the Rutaceae), Meliaceae (*Chloroxylon*, *Flindersia*), Olacineae, Rhamneae (secretory cavities with a papillose epithelium), Connaraceae (with sphaerocrystalline contents), Papilionaceae (also intramural glands, open secretory cavities, and cavities with a papillose epithelium and a bracket-epithelium, Fig. 57, p. 262), Caesalpinieae, Mimoseae (secretory cavities with bracket-epithelium), Rosaceae, *Myrtaceae sens. str. (in *Tristania* exceptionally with mucilaginous contents), Lythrarieae, Samydaceae, Passifloraceae, Araliaceae, Rubiaceae, Compositae, Primulaceae (occasionally with red crystalline contents), Myrsineae (Eumyrsineae and Maeseae, frequently with red crystalline contents; like canals in the axis, see also above), Styraceae (secretory cavities resembling intramural glands), *Myoporineae (excl. *Oftia* and *Zombiana*), Polygonaceae (secretory cavities sometimes formed by four epidermal cells), Podostemaceae, Piperaceae (side by side with secretory cells), Proteaceae (Fig. 173, p. 713, intramural glands), *Gonystylus*, Euphorbiaceae (only secretory cavities with bracket-epithelium); lastly, also in the genus *Panda*, which has not yet been assigned a definite position in the Natural System (see Pierre, in Bull. Soc. Linn. de Paris, 1896, p. 1256).

The **development of irregular secretory cavities** by the disorganization of portions of the tissue of the wood has been recorded in *Evodia* and *Zanthoxylon*

(Rutaceae, cf. § 16), *Carapa* (Meliaceae), *Dilodendron* (Sapindaceae), *Burkea* (Caesalpinieae) and *Terminalia* (Combretaceae). With this feature we may associate the formation of tragacanth in the species of *Astragalus* and the occurrence of gummosis in the species of *Acacia* and in the Pruneae. Lastly, the presence of mucilaginous or resinous or latex-like **secretions in the ordinary intercellular spaces** of the leaf or axis may likewise be mentioned here. This feature has been demonstrated in *Peganum*, the genus *Vahlia* (Fig. 67, p. 314), *Donatia* and *Roussea* (Saxifragaceae), *Lysimachia* and *Primula*, *Gentiana*, and *Cobaea* (Polemoniaceae), and probably occurs also in *Humulus* and some Acanthaceae.

§ 19. SECRETORY CANALS [1]. The secretory canals are here understood in an analogous sense to the secretory cavities discussed in § 18. They resemble the latter in their diverse contents and their varied mode of origin and have the same systematic value, which is often very considerable (characteristic of all the members in the Orders indicated by a * in the enumeration below). In determining their distribution the axis should first be examined, since in some cases the secretory canals do not enter the lamina of the leaf at all (e.g. in the Hypericineae, certain Araliaceae, &c.). The distribution of the secretory canals in the axis varies and is sometimes characteristic of certain taxonomic groups. They may occur in the pith, bast, pericycle, endodermis and primary cortex, rarely in the wood as well [2] (only in the Dipterocarpeae—but here their occurrence in the wood is perhaps quite general in axes of a certain thickness—and in certain Caesalpinieae). In the Altingieae, for example, the secretory canals are found only in the pith; in the Burseraceae or Anacardiaceae it is the secretory canals in the bast which are characteristic of their respective Orders, but in certain species of these Orders [3] canals are present also in the pith and primary cortex; in the Compositae the endodermal secretory canals are characteristic, &c. When the secretory canals penetrate into the leaf, they generally occupy the same position with reference to the vascular system as in the axis of the species in question, i.e. secretory canals situated in the bast of the vascular system of the veins correspond to those found in the bast of the axis, canals lying above the fibrovascular system of the veins to the medullary canals of the axis, and so on; but occasionally (Guttiferae pro parte, Fig. 27, *D*, p. 122) the canals also run freely in the mesophyll [4]. In some cases, moreover, an investigation of the secretory canals in the root is indispensable, although such an investigation can rarely be carried out systematically owing to lack of material. It will suffice to point out that the secretory canals in some of the Tubuliflorae (Compositae) are absent above the level of the cotyledons, and that the secretory canals, situated in the root in the Pittosporeae, Araliaceae, and Umbelliferae, occur in a characteristic position, viz. in the pericambium opposite the groups of wood and bast, belonging to the primary fibrovascular system.

For the vicarious occurrence of other types of secretory organs in place of the secretory canals of the Compositae, see under that Order in the following enumeration, and also § 18 (p. 1099).

Secretory canals have been observed in the *Hypericineae (only in the axis;

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[1] De Bary, Vergl. Anat., 1877, pp. 210 and 455.

[2] Interxylary secretory canals occur more frequently in the root (Umbelliferae, Compositae). For the occurrence of mucilage-canals or mucilage-cavities and other kinds of secretory cavities in the secondary wood, see §§ 16, 17, 18.

[3] In such cases the occurrence of secretory canals in the pith and primary cortex is generally only a specific character.

[4] The secretory canals running freely in the mesophyll occasionally give rise to transparent lines in the leaves, while those accompanying the vascular bundles of the veins sometimes produce translucent veins.

always in the bast, sometimes also in the pith, prim. cortex and pericycle), *Pittosporeae (pericycle, sometimes also in the bast), *Guttiferae (always in the pith and prim. cortex of the axis, in some cases also in the bast; in the leaf, either running freely in the mesophyll or in the veins, sometimes replaced by secret. cavities), Ternstroemiaceae (Bonnetieae, excepting *Archytaea* and *Bonnetia*; in the axis in the pith and prim. cortex, in some cases also in the bast), *Dipterocarpeae (always in the pith and ? second. wood, rarely? also in the bast), Rutaceae (in the centre of the pith in *Clausena punctata*), Simarubaceae (pith), *Koeberlinia* (bast), *Burseraceae (secret. canals always present in the bast, and side by side with them sometimes canals in the pith and prim. cortex), Celastrineae (veins of the leaf of *Mortonia* and margin of the leaf in *Pachystima*), Rhamneae (veins of the leaf in *Reynosia* pro parte, the canals being provided with a papillose epithelium), *Anacardiaceae (typical members of the Order always provided with secretory canals situated in the bast, but besides these there may be canals also in the pith and prim. cortex), *Juliania* (as in the previous case), Papilionaceae (prim. cortex in *Cordyla*, *Millettia* pro parte and *Myroxylon*), Caesalpinieae (in the secondary wood of *Copaifera*, *Daniella*, *Eperua*, *Kingiodendron*, *Oxystigma* and *Prioria*; in these genera sometimes also in the pith or cortex, as the case may be), Hamamelideae (margin of the pith in the Altingieae), Cacteae (in the cortex, the contents resembling latex in *Mammillaria* pro parte and *Leuchtenbergia*), *Umbelliferae (above all in the pericycle, but also in the pith, bast, and prim. cortex), *Araliaceae (excl. *Aralidium*, otherwise as in the Umbelliferae), Cornaceae (pith of *Mastixia*), Compositae (in members of all the thirteen tribes of Bentham and Hooker's system of classification; typically present in the root, and occasionally absent in the shoot, the canals in the latter case being replaced in the shoot by other types of secretory organs, viz. secretory sacs or laticiferous vessels; in the root there are always canals, which arise from the endodermis, but in addition to this, canals may be found in the primary cortex, the periphery of the pith, the secondary wood and bast of the root, or in the pericycle, the place of the canals being sometimes taken by secretory cavities), Myrsineae (see § 18), Gesneraceae (internal to the vasc. bundles of the stem and in an analogous position in the veins of the leaf, in *Klugia* and *Rhynchoglossum*), Podostemaceae (*Weddellina*, intercell. spaces resembling resin-canals ?), *Leitnerieae (at the margin of the pith).

§ 20. LATICIFEROUS CELLS[1] and secretory organs of a similar type. It is a familiar fact that the laticiferous cells (non-articulated laticiferous tubes) are long tubular branching elements, which are filled with various contents, the latter often being of the nature of latex or caoutchouc; the laticiferous cells are already differentiated as initial cells in the hypocotyl of the embryo, and in later stages their branches often traverse all the organs of the plant. The term 'non-articulated laticiferous tubes' thus refers to the course of development of these elements. It is not, however, possible to undertake a developmental investigation in each individual case; according to Chauveaud[2], moreover, it is not out of the question that, to take the case of the Apocynaceae for instance, some of the secretory organs, there described as laticiferous cells, are differentiated only at a later stage, and develop in a different way from that mentioned above, and according to F. E. Weiss[3] this is really true of the caoutchouc-cells of *Eucommia*, which cannot be distinguished from true laticiferous cells, unless their mode of development is studied. For these reasons only those Orders or genera are enumerated under the heading 'laticiferous cells' in the following review, some at least of the species of which have been investigated developmentally with positive results; the remainder are comprised under the heading of 'secretory organs resembling laticiferous cells.' The detailed structure of the laticiferous tubes, viz. the size of their lumina and the nature of their walls and contents, is only of trifling systematic value. It is also necessary to ascertain, whether the elements in question occur in all

[1] Cf. De Bary, Vergl. Anat., 1877, p. 199.
[2] In Ann. sc. nat., sér. 7, t. xiv, 1891.
[3] In Transact. Linnean Soc. London, 2 ser., vol. iii, Bot., 1892.

the vegetative organs, for in some cases they do not enter the leaf (see e.g. under Moraceae, p. 1059). For transitions to laticiferous vessels (in the Apocynaceae), see § 21.

Laticiferous cells, the branches of which may run in the pith, bast, and primary cortex[1], in the veins of the leaf, and occasionally also freely in the mesophyll, but are chiefly found accompanying the bast-groups, occur in all (?) Apocynaceae and Asclepiadeae, in many Euphorbiaceae, in the genera *Humulus* and (?) *Cannabis* (Cannabineae), and lastly in many, perhaps all, Moraceae.

Secretory organs resembling laticiferous cells, (some of them perhaps of secondary origin, as has been proved to be the case in *Eucommia* (Trochodendraceae), are also known to occur in *Plagiopteron* (Tiliaceae), *Coula, Eganthus, Heisteria, Minquartia* and *Ochanostachys* (Olacineae), *Celastrus, Euonymus, Gymnosporia* pro parte[2], *Mystroxylon* and *Wimmeria* (Celastrineae), *Campylostemon, Hippocratea* pro parte and *Salacia* pro parte (Hippocrateaceae) and *Urera* (Urticaceae). Caoutchouc-cells, like those of *Eucommia*, are closely related to the elongated secretory sacs, mentioned under II in § 14 (p. 1097).

The secretory organs discussed in this section are sometimes visible even to the naked eye or with the help of a lens; this is the case, when their caoutchouc-like contents appear in the form of delicate elastic threads[3] on breaking through the leaves and branches, or when the laticiferous cells give rise to transparent lines in the leaves.

§ 21. Laticiferous Vessels. These elements arise by the absorption of the transverse walls in rows of cells, which are either simple or arranged to form a network; they occur in the same tissues of the axis and leaf as the laticiferous cells, but are chiefly associated with the phloem. In some cases they also run freely in the mesophyll, while in the Papayaceae they are even found traversing the soft xylem-mass.

Laticiferous vessels have been demonstrated: among the Papaveraceae, in the genera *Papaver, Argemone, Roemeria* and *Chelidonium* (? also in *Meconopsis* and *Platystemon*); in the tubers of *Tropaeolum* ? (Geraniaceae); among the Olacineae, in the genera *Endusa* and *Cardiopteris*; in all the Papayaceae; in all the Cichoriaceae, and, outside the limits of this tribe, in the genera *Gundelia, Gazania, Carlina* and *Atractylis* (Compositae); in all Campanulaceae and Lobeliaceae with the exception of *Sphenoclea*; among the Convolvulaceae, in the genera *Dichondra* and *Falkia* (in the latter genus as yet demonstrated only in the floral organs); and among the Euphorbiaceae, in the genera *Hevea* and *Manihot*.

Transitions between rows of laticiferous sacs and laticiferous vessels, as evidenced by the occurrence of perforations on the transverse walls of the former, have been observed in the Orders Sapotaceae and ? Convolvulaceae, while transitions between elongated secretory sacs (see § 14) and laticiferous vessels have been met with in certain Compositae; lastly, transitions between laticiferous cells and laticiferous vessels are found in the petals of certain Apocynaceae. All these features require careful reinvestigation.

Trichomes, which enter into connexion with the system of laticiferous vessels, are found in some of the Cichoriaceae (Fig. 103, *O*, p. 458), while papillose terminations of the laticiferous tubes occur in *Siphocampylus* (Lobeliaceae).

§ 22. Oxalate of Lime[4]. The diverse forms of excretion of oxalate of lime, as also its absence and its distribution in the various organs and tissues of a plant, afford a whole series of valuable anatomical features.

[1] Laticiferous cells occur in the wood only in so far as branches of the cortical laticiferous tubes sometimes traverse the medullary rays of the wood and finally penetrate into the pith.

[2] See Loesener, in Notizbl. Berliner Garten n. 42, 1908, p. 64.

[3] Such cases of 'spinning' on the part of the caoutchouc-like contents have been observed in the secretory organs of *Eucommia, Plagiopteron, Celastrus, Euonymus, Mystroxylon, Wimmeria, Hippocratea*, and *Salacia* (mentioned above under the heading of 'secretory organs resembling laticiferous cells'), in the laticiferous cells of *Parameria* (Apocynaceae) and in the 'elongated secretory sacs' of *Tinomiscium* (Menispermaceae, included under II in § 14).

[4] Cf. Kohl, Kalksalze und Kieselsäure in der Pflanze, Marburg, 1889; Poli, Cristalli di ossalato calcico, Roma, 1882 (abstr. in Bot. Centralbl., 1882, ii, p. 311); and also Buscalioni, in Malpighia, x, 1896, where a general idea of the literature dealing with oxalate of lime can be obtained.

We may distinguish the following modes of excretion of oxalate of lime: 1. **Ordinary solitary crystals** (i.e. rhombohedral crystals ('Hendyoëder') belonging to the monoclinic system), which are of large but variable size, and are very widely distributed) and their modifications and twin-crystals; 2. **Styloids**[1] or columnar crystals (i.e. elongated prismatic crystals belonging to the monoclinic system) or twin-forms of such crystals, the latter, when typically differentiated, recalling the well-known crystals characteristic of gypsum; regarded from the systematic point of view, styloids commonly replace raphides and occasionally show transitions to the forms of crystals, discussed under 4; 3. **Octahedral or prismatic crystals**, belonging to the quadratic or monoclinic systems and mostly of rather small size; 4. **Acicular crystals**, i.e. small needle-shaped or fusiform crystals, which sometimes merge into small crystals of prismatic shape or crystals, which are almost of the nature of styloids; when elongated, the acicular crystals come to resemble raphides[2], whilst, when they are very small, they appear like sand; in most cases large numbers of acicular crystals occur in one and the same cell; 5. **Clustered crystals**, which are composed of individual crystals belonging to the quadratic or monoclinic systems; 6. **Sphaerites** (Sphere-crystals), i.e. bodies resembling clustered crystals and having a sphaerocrystalline structure with a smooth or rather smooth surface; 7. **Raphides**[3], i.e. long acicular crystals, large numbers of which lie parallel to one another in a cell containing mucilage; 8. **Crystal-sand** (Fig. 134, p. 579), which is composed of numberless small crystals, completely filling the cells and, in the case of typical crystal-sand ('sable tétraëdrique'), having a tetrahedral form[4]. The systematic value of these forms of crystals varies very considerably. In some cases a certain form of crystal is characteristic of an entire Order, while in other cases it serves to distinguish only genera or species; and this applies to all the different kinds of crystals above enumerated, even to those which are specially typical and have the greatest systematic value (viz. raphides, styloids, and crystal-sand). The three forms of crystals just named, for example, are of strikingly small systematic value in the Order Thymelaeaceae.

Several forms of crystals may occasionally occur side by side in one and the same plant, the chief combinations being solitary and clustered crystals, raphides and clustered crystals, raphides and styloids, clustered crystals and crystal-sand (the clustered crystals sometimes even being enclosed in the cells containing the crystal-sand), and so on; in such cases the various forms of crystals are found either in the same or in different tissues, or even in different organs of the plant. In other species or genera, or even Orders, however, only one form of crystal is present. In employing the occurrence of oxalate of lime for systematic purposes it must be borne in mind that this salt has been shown to be capable of re-entering into the metabolism of the plant, and that clustered crystals often occur alone in the primary cortex in early stages, while solitary crystals only appear subsequently.

Oxalate of lime has hitherto[5] **not been demonstrated in the**: Fumariaceae, Cruciferae, Stackhousieae, Crossosomataceae, Lobeliaceae, Monotropeae, Lennoaceae, Primulaceae, Salvadoraceae, *Desfontainea*, Gentianeae-Menyanthoideae, Cuscuteae ?,

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[1] Radlkofer, in Sitz.-Ber. Münch. Akad., 1890, p. 114; see also Rothert and Zalenski, Bes. Kategorie von Krystallbeh., Bot. Centralbl., 1899, iv, p. 1 et seq.

[2] These shorter acicular crystals are rarely (see Gentianeae) enclosed in cells containing mucilage.

[3] See also A. Fuchs, Bau der Raphidenzelle, Öst. bot. Zeitschr., 1898, p. 324 et seq.; and Kohl, Raphidenzelle, Bot. Centralbl., 1899, iii, p. 273 et seq.

[4] See Arcangeli, in Nuov. Giorn. bot. Ital., xxiii, 1891.

[5] The following statements refer solely to the vegetative organs (especially the axis and the leaf). For it frequently happens that crystalline elements occur in the reproductive organs (testa, etc.), although it has been found impossible to demonstrate them in the vegetative organs of the same plant (e.g. in certain Caryophylleae, Valerianeae, and Primulaceae).

Orobanchaceae and Plantagineae ?, besides numerous genera and species belonging to other Orders.

Ordinary solitary crystals and clustered crystals (sometimes side by side with a third form) have been observed in the same or in different species of the following Orders and genera respectively: Trochodendraceae, Anonaceae, Menispermaceae (solitary crystals not very abundant, clustered crystals rare), Berberideae, Capparideae, Cistineae (solit. cryst. rare), Violarieae, Canellaceae, Bixineae, Pittosporeae, Tremandreae, Polygaleae, Vochysiaceae, Caryophylleae (solit. cryst. very rare), Portulaceae, Tamariscineae, Hypericineae, Guttiferae, Ternstroemiaceae, Dipterocarpeae, *Lophira*, Malvaceae, Triplochitonaceae, Sterculiaceae, Tiliaceae, Lineae (clust. cryst. rare), Humiriaceae, Malpighiaceae, Zygophylleae, Geraniaceae, Rutaceae, Simarubaceae, *Balanites*[1], Ochnaceae, Luxemburgiaceae, *Wallacea*, Burseraceae, Meliaceae, Chailletiaceae, Olacineae, Ilicineae, Cyrilleae, Celastrineae, Hippocrateaceae, Pentaphylacaceae, Corynocarpaceae, Rhamneae, Ampelidaceae, Sapindaceae, Hippocastanaceae, Aceraceae, Staphyleaceae, Sabiaceae, Anacardiaceae, Coriarieae (clust. cryst. only in the rhizome), Moringeae, Caesalpinieae, Mimoseae (clust. cryst. rare), Rosaceae, Saxifragaceae, Hamamelideae, *Ostrearia*, Bruniaceae, Rhizophoraceae, Combretaceae (chiefly clust. cryst.), Myrtaceae, Lecythidaceae, Lythrarieae, Samydaceae, Passifloraceae, Cacteae, Umbelliferae (solit. cryst. rare), Araliaceae, Cornaceae, Caprifoliaceae, Rubiaceae (solit. cryst. rare), Compositae (rare), Vacciniaceae, Ericaceae, Epacrideae, Diapensiaceae, Plumbagineae, Myrsineae, Sapotaceae, Ebenaceae, Styraceae, Apocynaceae, Asclepiadeae, Loganiaceae, Convolvulaceae, Solanaceae, Scrophularineae (rare), Columelliaceae, Bignoniaceae, Pedalineae, Myoporineae, Verbenaceae (solit. and clust. cryst. rare), Labiatae (rare in the vegetative organs), Amarantaceae (solit. cryst. rare), Chenopodiaceae (solit. cryst. rare), Basellaceae, Batideae, Polygonaceae, Podostemaceae, Aristolochiaceae (solit. cryst. rare), Piperaceae (*Symbryon*), Proteaceae (not abundant), Thymelaeaceae, *Gonystylus*, *Geissoloma*, Loranthaceae, Santalaceae, *Myzodendron*, *Grubbia*, Balanophoreae, Euphorbiaceae, Buxaceae, Balanopseae, Ulmaceae, Moraceae, Urticeae, Platanaceae, Juglandeae, Myricaceae, Casuarineae, Cupuliferae, Salicineae, Lacistemaceae.

Clustered crystals alone, or accompanying some other form of crystal (with the exception of ordinary solitary crystals),—in the latter case in the same or in different species—have been observed in the following Orders and genera respectively: Ranunculaceae (rare), Magnoliaceae, Nymphaeaceae, Sarraceniaceae, Papaveraceae, Frankeniaceae, Elatineae, *Lophira*, *Monotes*, Chlaenaceae, Melianthaceae, *Penthorum*, *Myrothamnus*, Halorageae (Fig. 72, *A*, p. 337), Melastomaceae (clust. cryst. occasionally reduced to short and thick solit. cryst.), Onagrarieae, Loaseae, Turneraceae, Papayaceae, Begoniaceae, Ficoideae, Valerianeae (rare), Dipsaceae, Calycereae, Candolleaceae, Campanulaceae (only in *Sphenoclea*), *Plocosperma*, Gentianeae (only small clust. cryst.), Polemoniaceae (clust. cryst. rare and of small size), Hydrophyllaceae, Boragineae, Gesneraceae, Acanthaceae, *Zombiana*, Labiatae, Nyctagineae, Illecebraceae, Chenopodiaceae, Phytolaccaceae (rare), Nepenthaceae, Piperaceae (excl. *Symbryon*), Chloranthaceae, Myristicaceae, *Octolepis*, Penaeaceae, Daphniphyllaceae, Cannabineae, Leitnerieae, Empetraceae, but also in certain genera or species belonging to other Orders.

Rhombohedral solitary crystals are found alone or accompanied by some other form of crystal (excluding clustered crystals)—in the latter case in the same or in different species—in the Rhaptopetalaceae, *Koeberlinia*, Octocnemaceae, Connaraceae, Crassulaceae, Cucurbitaceae (rare), Hernandiaceae (only in *Illigera obtusa*), and in most Papilionaceae and Mimoseae, and in numerous genera or species of other Orders.

As regards the form of the clustered crystals, we may note at this point that the well-known star-shape is the commonest. Clustered crystals, which are made up of acicular or quadratic (Begoniaceae, Lecythidaceae, Proteaceae, Fig. 173, p. 713) crystals, are more rarely found. Special forms requiring mention are the clustered crystals of certain Combretaceae, which are like stars with unequal rays ('krippensternartig'), and the clustered crystals of species of *Centradenia* (Melastomaceae, Fig. 79, *A*, p. 362), which are found combined with styloids.

Sphaerites have been observed only in certain Berberideae, Tamariscineae (*Fouquieria*), Geraniaceae, Aceraceae, Sabiaceae[2], Papilionaceae, Rosaceae, Crassulaceae, Combretaceae (according to Höhnel, in Bot. Zeit., 1882), Melastomaceae, Lythrarieae, Cacteae (Fig. 93, p. 413), Rubiaceae, Asclepiadeae, Solanaceae, Phyto-

[1] According to Van Tieghem, Ann. sc. nat., sér. 9, t. iv, 1906.
[2] According to Dihm, Beih. z. Bot. Centralbl., xxi, Ab. i, 1907.

laccaceae, Balanophoreae, Euphorbiaceae and Empetraceae; according to Hegelmaier, they also occur in certain Caryophylleae, but are there confined to the testa.

Octahedral or prismatic crystals of the quadratic system (*q*) (which in most cases are at once distinguishable from monoclinic crystals by their smaller size), as well as twin-forms of such crystals, or **small prismatic or fusiform to acicular crystals** (*a*) (which occasionally, when of sufficient length, resemble raphides), or small crystalline bodies of diverse other shapes (rounded, &c.)[1], have been met with in the following Orders: Ranunculaceae (*q*), Calycanthaceae (*q*), Magnoliaceae (*q*), Menispermaceae (*a*), (also transitions to crystal-sand and styloids), Capparideae, Resedaceae (rare), Canellaceae (*q*), Guttiferae, Sterculiaceae, Zygophylleae (*a*), *Peganum* (*a*), Simarubaceae (Fig. 42, *B*, p. 183), Ampelidaceae (*a*), Aceraceae, Papilionaceae, Caesalpinieae[2], Saxifragaceae (*a*), Melastomaceae (*a*), Lythrarieae, Onagrarieae, Begoniaceae (*q*), Datisceae (*a*), Cacteae (*q*), Ficoideae, Araliaceae, Rubiaceae (*a*), Compositae (*q*, *a*), Goodeniaceae, Campanulaceae (*q*, *a*), Myrsineae-Theophrasteae, Styraceae, Oleaceae (*a*), Apocynaceae (*a*), Loganiaceae (*q*, *a*), Gentianeae (*a*), Polemoniaceae (*a*), Boragineae (*a*), Convolvulaceae (*a*), Solanaceae (*q*), *Retzia* (*a*), Scrophularineae (*q*, *a*), Lentibularieae, Gesneraceae (*q*, *a*), Bignoniaceae (*a*), Pedalineae, Acanthaceae (*a*), Myoporineae (*a*), Selagineae, Verbenaceae (*q*, *a*), Labiatae (*q*, *a*), Nyctagineae (*a*), Chenopodiaceae (*q*), Basellaceae (*q*), Phytolaccaceae (rare and observed only in the ovary), Cytinaceae (*q*), Aristolochiaceae (*a*), Piperaceae (*a*), Chloranthaceae (very rare), Myristicaceae (*a*), Monimiaceae (*a*), Laurineae (*a*), Hernandiaceae (*a*), Gomortegaceae (*a*), Elaeagnaceae (*a*), Moraceae.

Bundles of **raphides** are found in the following Orders, being of constant occurrence in those marked with a *: *Dilleniaceae, Ternstroemiaceae (Marcgravieae and Sauraujeae excl. *Stachyurus* and *Pelliciera*, Fig. 29, *A*, p. 129), Geraniaceae, Rutaceae, Zygophylleae (*Peganum*), Ochnaceae (*Tetramerista*), *Ampelidaceae (Fig. 52, *B*, p. 223), Melianthaceae, *Hydrangeae (Saxifragaceae), *Onagrarieae (excl. *Trapa*), Ficoideae, Rubiaceae, Gesneraceae (*Napeanthus repens*, J. D. Smith !), Nyctagineae, Phytolaccaceae (Euphytolacceae and *Agdestis*), Urticeae (*Laportea*), Thelygoneae.

Typical styloids have been recorded in the following Orders or genera, as the case may be: Pittosporeae (constant), Ternstroemiaceae, Zygophylleae, Geraniaceae, Rutaceae, Simarubaceae, Ilicineae, Rhamneae, Sapindaceae, Melianthaceae, Rosaceae, Saxifragaceae, Melastomaceae (often distinctive of groups of genera, not constant in *Centradenia*), Lythrarieae, Onagrarieae, Ficoideae, Caprifoliaceae, Rubiaceae, Apocynaceae, Asclepiadeae, Loganiaceae, *Plocosperma*, Nyctagineae, Phytolaccaceae (Rivineae), Thymelaeaceae (Fig. 174, *D*, p. 717), Euphorbiaceae (not constant in *Phyllanthus*), Urticeae (*Laportea*). We have already noticed above that styloids often take the place of the bundles of raphides. The styloids are commonly confined to the bast, while some other form of crystal occurs in the remaining tissues of the species in question. At this point we may also include: (*a*) **crystals resembling styloids**, but shorter than typical styloids, such crystals being found in certain Menispermaceae, Tiliaceae, Zygophylleae, Celastrineae, Papilionaceae, Ficoideae, Columelliaceae, Nyctagineae, Phytolaccaceae, Thymelaeaceae, Euphorbiaceae, Buxaceae, Ulmaceae and Juglandeae; (*b*) small rod-shaped crystals, which likewise resemble styloids, and are combined with one another so as to have the shape of a widely open V or W, or the form of an I; crystals of this type occur in certain Menispermaceae, Malpighiaceae, Sapindaceae, Papilionaceae (Fig. 58, p. 265), Mimoseae, Rosaceae, Loganiaceae and Euphorbiaceae; (*c*) crystals, which are shaped like styloids, but vary in length, and occur to the number of several in the same cell; they have been observed in *Krameria* (Polygaleae), certain Cacteae, *Pisonia* (Nyctagineae, Fig. 154, *C*, p. 646), *Rivina* and *Villamilla* (Phytolaccaceae).

Typical **crystal-sand** ('sable tetraédrique'), which occasionally includes clustered crystals (cl. cr.) or even solitary crystals (sol. cr.), has been observed in the Rutaceae (cl. cr.), Olacineae (sol. cr.), Sapindaceae, Saxifragaceae, Crassulaceae, Araliaceae, Cornaceae, Caprifoliaceae, Rubiaceae, Sapotaceae (only in the latici-

[1] All these forms of crystals are considered jointly here, because they often occur side by side in different species of an Order or even in the same species, and because it is sometimes difficult to draw a sharp limit between the different forms. The addition of the letter *q* or *a* in the subsequent enumeration is not intended to indicate that the forms of crystals, represented by these letters, are the only ones occurring in the Order in question, but testifies solely to the occurrence of such crystals, in so far as it has been definitely established.

[2] In *Detarium*, according to recent observations of my own.

ferous sacs), Loganiaceae, Boragineae, Nolaneae, Solanaceae (cl. cr.), Amarantaceae, Chenopodiaceae, Thymelaeaceae, Buxaceae; **powdery or finely granular crystal-sand** has been observed in *Acanthophyllum* (Caryophylleae), *Dysphania, Gymnocarpos* and *Habrosia* (Illecebraceae), and *Saruma* (Aristolochiaceae); in the last of these genera it is present only in the terminal cells of the trichomes. We may include here the following special features: (*a*) the occurrence of a kind of crystal-sand above the gelatinized membranes of the epidermal cells in the leaves of certain species of *Rourea* (Connaraceae); (*b*) crystal-sand, consisting of tetrahedral granules and small acicular and prismatic crystals, in *Leucaster* (Nyctagineae); (*c*) crystal-sand, composed of small acicular and prismatic crystals, in *Calandrinia* (Portulaceae), and crystal-sand, showing a similar composition, in *Protoschwenkia* (Solanaceae) and *Buxus* (Buxaceae); (*d*) coarsely granular crystal-sand, consisting of quadratic or short prismatic crystals, in *Dunalia* (Solanaceae), *Gallesia* (Phytolaccaceae, Fig. 160, p. 666) and members of the tribe Monimieae; lastly, (*e*) a kind of crystal-sand (?), also in two species of *Meliosma* (Sabiaceae). When large numbers of acicular crystals occur in the same cell, they are occasionally reduced so as to form a kind of sand (e.g. in certain Menispermaceae, Melastomaceae, Gentianeae, Piperaceae and Elaeagnaceae). A number of small crystals are commonly found accompanying solitary or clustered crystals, especially in the large crystal-idioblasts of the leaf, but such cases have not been taken into consideration in the preceding review of the distribution of crystal-sand.

As a rule the crystalline elements are found in the lumina of the cells, but in some cases (and this applies especially to solitary and clustered crystals) they are embedded in a thickened part of the cell-wall; in the latter case they are either completely enveloped by the cell-membrane or lie in the middle of the lumen of the cell enclosed in a sack of cellulose, after the manner of Rosanoff's clustered crystals, this sack being connected with the cell-wall by means of one or more beams of cellulose [1]. We can only attribute systematic value to these features, when the differentiation of the structure in question is particularly typical (e.g. in the Papilionaceae, *Citrus* or the Rhizophoraceae). Features of greater systematic importance are afforded by the deposition of numerous small crystalline granules resembling crystal-sand in the walls of the cells of various tissues in certain Crassulaceae (Fig. 70, *D*, p. 321), Cacteae, Ficoideae, Nyctagineae (Fig. 154, *A*, p. 646), and Euphorbiaceae (in *Croton*, here in the tissue of the cork), and the deposition of large crystals in and on the cell-walls in the Nymphaeaceae (Fig. 11, p. 47). An apparent embedding of rather large crystals is found in the crystal-sclerenchyma of certain Magnoliaceae (Fig. 4, p. 29), Combretaceae, Rubiaceae and Loranthaceae (Fig. 177, p. 728), and in the crystal-hairs of the Guettardeae (Fig. 101, *B*, *C*, p. 446); the former has already been discussed in § 9 (pp. 1090, 1091); in the latter the cell-wall undergoes thickening to such an extent, that really nothing but the spaces filled by the crystals remains to represent the lumina of the hairs.

The various forms of crystals described in the preceding pages occur in the different tissues of the leaf and axis, although sometimes confined to a definite tissue. The shape and size of the cells, containing the crystals, correspond to the shape and size of the crystalline deposits themselves. Cells containing crystals are often not distinguished from the neighbouring cells, but in other cases they appear as idioblasts. The following **special types of crystal-receptacles** are of systematic importance: (*a*) crystal-idioblasts actually or apparently situated in the epidermis (see § 2, p. 1075); (*b*) cells containing clustered crystals or sphaerites and projecting towards the exterior in the form of a papilla or hair (in certain Euphorbiaceae, Fig. 180, *R*, *S*, p. 748); (*c*) small cells, containing clustered crystals and bordering on the intercellular spaces into which they often project like papillae, in certain Nymphaeaceae (Fig. 11, *B*, p. 47), Halorageae (Fig. 72, *A*, p. 337), and Onagrarieae (*Trapa*); (*d*) crystal-idioblasts,

[1] See also Wittlin, Kalkoxalattaschen, Bot. Centralbl., 1896, iii, p. 33 et seq. and Möbius, Festlegung der Kalksalze u. Kieselsäure, Ber. deutsch. bot. Gesellsch., 1908, p. 29 et seq.

provided with a gelatinized or merely thickened inner wall, in the mesophyll of certain Dipterocarpeae; (*e*) small cells bearing clustered crystals, which bring about a blocking up of the respiratory cavities (*Pilocarpus*, Rutaceae); (*f*) transversely septate palisade-cells with a single clustered or solitary crystal in the compartments; (*g*) idioblasts in the tissue of the leaf, filled with a solitary or clustered crystal, such idioblasts having wide lumina and often being distinguished by their spherical shape; (*h*) groups of cells with clustered crystals in the mesophyll (*Pemphis*, Lythrarieae); (*i*) entire layers of crystal-cells, lying parallel to the surface of the leaf (e.g. in certain Celastrineae, Melastomaceae or Samydaceae); (*j*) sheaths composed of crystal-cells in the veins of the leaf; (*k*) the 'cristarque'-cells of the leaf and axis (see §§ 7 and 51); and (*l*) chambered parenchyma with solitary crystals (in the wood and bast) or clustered crystals (in the bast). A special and peculiar mode of occurrence of acicular crystals is found in the fluke-cells of the anchor-like shaggy hairs of *Cranocarpus* (Papilionaceae, Fig. 59, *G*, p. 269) and in the terminal cells of the stinging hairs of *Tragia* and other Euphorbiaceae (Fig. 180, *P*, *Q*, p. 748).

It remains to mention that the crystalline forms of oxalate of lime (and especially large clustered or solitary crystals, styloids, which often traverse the entire thickness of the leaf at right angles to its surface, and bundles of raphides, orientated in the same direction) frequently give rise to delicate or distinct transparent dots in the leaf, while raphides, when lying parallel to the surface of the leaf, may produce transparent striulae.

§ 23. SPHAEROCRYSTALS (sphere-crystals)[1]. Sphaerocrystals which do not consist of oxalate of lime have been observed in herbarium- or alcohol-material of a number of plants. Only in a few cases is their chemical nature at all clearly known. In some Orders they consist of inulin, in the Ampelidaceae perhaps of cissose, in certain Cruciferae and Rutaceae of a substance resembling hesperidin, in certain *Euphorbias* of calcium phosphate and calcium malophosphate, &c.

Inulin[2] has been demonstrated in: Violarieae, Malpighiaceae[3], Droseraceae, Compositae, Candolleaceae, Goodeniaceae, Campanulaceae, Lobeliaceae and Myoporineae; sphaerocrystals of a different chemical composition in: Ranunculaceae, Menispermaceae, Cruciferae, Capparideae, Violarieae, Ternstroemiaceae, *Strasburgeria*, Geraniaceae, Rutaceae, Ilicineae, Ampelidaceae, Papilionaceae, Crossosomataceae, Lythrarieae, Caprifoliaceae (*Adoxa*)[4], Passifloraceae, Cacteae, Ficoideae, Rubiaceae, Valerianeae, Calycereae, Compositae, Campanulaceae, Asclepiadeae, Nolaneae, Bignoniaceae, Verbenaceae, Labiatae, Basellaceae, Nepenthaceae, Chloranthaceae, Thymelaeaceae, Santalaceae, *Myzodendron*, Euphorbiaceae, Moraceae, Urticeae, Salicineae. For sphaerites of oxalate of lime, see § 22, p. 1105.

§ 24. CRYSTALLOIDS[5]. Crystalloids, which occur in the nuclei, the chromatophores or the cell-sap, and are either crystalline or of some other shape, have a wider distribution than has generally been supposed.

They are found in certain Berberideae, Nymphaeaceae, Capparideae, Caryophylleae, Lineae, Geraniaceae, Aceraceae, Papilionaceae (according to Baccarini, in the floral organs), Halorageae, Passifloraceae (spindle-shaped), Cacteae (spindle-

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[1] Hansen, in Arb. bot. Inst. Würzburg, iii, 1884; Leitgeb, in Mitteil. bot. Inst. Graz, 1888, Heft 2, p. 257 et seq.; Baccarini, in Malpighia, 1888, p. 1 et seq.; see also Schaarschmidt, in Magyar növenyt. lapok, 1881, p. 134 et seq. (abstr. in Bot. Centralbl., 1882, i, p. 46; and Just, 1882, i, p. 412).

[2] Gr. Kraus, in Bot. Zeit., 1875, p. 171, and 1877, p. 329; H. Fischer, in Cohn, Beitr., viii, 1898, p. 53 et seq.; Bay, Materials for a monograph of Inulin, Transact. Acad. S. Louis, vi, 1895, p. 151 et seq.

[3] See the papers by Hartwich, &c., cited in the literature-supplement, p. 1171.

[4] According to Eichinger, Diss., Munich, 1907.

[5] Leitgeb, Krystalloide in Zellkernen, Mitteil. bot. Instit. Graz, 1888, p. 113 et seq.; Zimmermann, Beitr. z. Morph. u. Biol. d. Pflanzenzelle, Tübingen, Heft 1, 1890, p. 54 et seq., and Heft 2, 1891, p. 112 et seq.; Stock, Proteinkrystalle, in Cohn, Beitr., vi, 1893, p. 213 et seq.

shaped, annular, or filiform, Fig. 93, p. 413), Droseraceae (as in the Cacteae), Araliaceae, Candolleaceae, Campanulaceae, Ericaceae, Oleaceae, Gentianeae, Convolvulaceae, Scrophularineae, Lentibularieae, Gesneraceae, Bignoniaceae, Verbenaceae, Amarantaceae, Phytolaccaceae, Nepenthaceae, Euphorbiaceae, Urticeae.

§ 25. Other Cell-Contents. The following enumeration deals with cell-contents other than those hitherto mentioned; the deposits in question for the most part occur only in herbarium-material and are rarely found in the living plant as well; the latter is the case with the deposits of gypsum, occurring in the epidermis of certain Capparideae (Fig. 18, *E*, *F*, p. 68), and the characteristic clustered and solitary crystals of the Salvadoraceae, which consist of an unknown organic salt of lime (Fig. 120, *A*, *B*, p. 527).

Apart from the prismatic crystals of gypsum, found in the epidermis of the leaf of certain Capparideae, and the peculiar crystalline elements of the Salvadoraceae, the following special contents have been observed: (*a*) crystalline bodies of diverse kinds and of unknown chemical composition, in certain Berberideae (Fig. 9, p. 44), Nymphaeaceae, Polygaleae, Ternstroemiaceae, Malvaceae, Zygophylleae (here in part also present in the intercellular spaces), *Gunnera*, Onagrarieae, Umbelliferae, Myoporineae, Selagineae, Polygonaceae and Piperaceae; (*b*) crystals of hesperidin in certain Rutaceae (Fig. 40, p. 175); (*c*) crystals of carotin in certain Onagrarieae and Scrophularineae; (*d*) berberin, which gives a yellow coloration to the wood, in the Ranunculaceae, Menispermaceae, and Berberideae; (*e*) rhamnocathartin, filling the medullary rays of the cortex with yellow contents, in the Rhamneae; (*f*) cissose in the Ampelidaceae; (*g*) saponin-like substances[1] in the Caryophylleae, Sapindaceae, Papilionaceae, Rosaceae (*Quillaja*) and Cacteae; (*h*) crystals of quinine in the *Cinchona*-barks; (*i*) crystals of cumarin in the leaves of *Liatris odoratissima* (Compositae); (*j*) scutellarin in the Labiatae; (*k*) oroxylin, in the form of a green wax-like substance, in *Oroxylum* (Bignoniaceae); (*l*) balanophorin, a body resembling wax, in the Balanophoreae; (*m*) crystals of indigo or bodies, consisting of indican, in many Papilionaceae (secretions containing indican also in the secretory cells of *Aristolochia Lindeniana* var., and in the secretory cavities of certain Olacineae, these secretions taking on a blue colour with eau de Javelle; for blue cystoliths, see under Acanthaceae, p. 1019); (*n*) lastly, alumina-bodies[2] in the mesophyll and cortex of the species of *Symplocos* (Styraceae).

As a general rule no very great degree of systematic value can be attributed to the occurrence of fat-bodies[3], which are found in the assimilatory tissue (especially the palisade-tissue) in herbarium-material of species belonging to numerous Orders, and are occasionally doubly refractive. For the distribution of these bodies, see chiefly Petit, who points out that they are rare in the Apetalae and in the Monocotyledons. With the fat-bodies we may class the small caoutchouc-bodies, which occur side by side with the former in the Celastrineae, and are described as characteristic of the Hippocrateaceae and Sapotaceae.

For the formation of tragacanth and the occurrence of gummosis, see § 18, p. 1101.

§ 26. Silica[4]. It is a familiar fact that silica occurs both as an incrustation on the cell-wall and as a mass filling the lumen of the cell. **Silicification of the cell-membrane** is a very widely distributed phenomenon, which more particularly affects the integumental tissue, and chiefly its outer walls. Silicification of the walls of hairs is of very frequent occurrence, and silicification of groups of epidermal cells is likewise a common feature; the silicified cells in

[1] Regarding these bodies, see Kunkel, in Arb. d. pharmakolog. Inst. Dorpat, vi, 1891, p. 5; Th. Waage, in Pharm. Centralhalle, 1892, p. 657; Heyl, in Archiv d. Pharm., 1901, p. 451; and Weil, Saponinsubst., Diss., Strassburg, 1901, also in Archiv d. Pharm., 1901, p. 363.

[2] Radlkofer, in Ber. deutsch. bot. Gesellsch., 1904, p. 188 et seq.

[3] Radlkofer, in Sitz.-Ber. Münch. Akad., 1889, p. 267 and 1890, p. 124; Petit, Globules réfringents, Comptes rendus Acad. Paris, cxxxiii, 2e sém., 1901, p. 1250 and Sphérulins, loc. cit., cxxxv, 2e sém., 1902, p. 991.

[4] De Bary, Vergl. Anat., 1877, p. 108; Kohl, Kalksalze u. Kieselsäure, 1889, p. 197 et seq.

the latter case are often grouped round about silicified hairs or function as basal cells bearing such hairs, and are not uncommonly visible to the naked eye as small rough knobs on the surface of the dry leaf. In other cases spherical or hemispherical groups of mesophyll-cells, or groups composed of epidermal cells and the subjacent cells of the palisade-tissue undergo silicification, those parts of the walls, which abut on one another, being affected; these walls are often considerably thickened or may even be provided with cystolith-like protuberances (see Fig. 166, *G*, p. 684). In other cases again, isolated cells of the mesophyll are silicified. The features last mentioned are sometimes of relatively great systematic value (Olacineae). Apart from that, the tendency to form silicified cells is characteristic of certain Orders (e.g. Boragineae and Aristolochiaceae). Groups of silicified cells, consisting of a malformed stoma and the neighbouring epidermal cells, may commonly be observed, but their occurrence is of no value for systematic purposes. It remains to mention that carbonate of lime often occurs side by side with the silica in the silicified cell-walls [1].

Cells with strongly silicified membranes have been observed in the following Orders: Dilleniaceae (epidermal cells, mesophyll, and spiny hairs), Calycanthaceae (hairs and their subsidiary cells), Magnoliaceae (epid. cells), Trochodendraceae (epid. cells + palisade-cells), Menispermaceae (special groups of epid. cells), Burseraceae (epidermis), Olacineae (cells of the mesophyll, solitary or in groups, Tribe Olaceae), Philadelpheae (epidermis), Caesalpinieae (cells of the mesophyll), Mimoseae (epid. cells + pal.-cells), Chrysobalaneae (epidermis, cells of the mesophyll, small knobs due to the hairs), Bruniaceae (epidermis), Halorageae (small knobs due to the hairs), Combretaceae (epidermis), Cucurbitaceae (cells of the mesophyll, small knobs due to the hairs), Rubiaceae (epidermis), Compositae (small knobs due to the hairs), Goodeniaceae (epidermis + cells of the mesophyll), Campanulaceae (reduced hairs), Oleaceae (small knobs due to the hairs), Hydrophyllaceae (small knobs due to the hairs), Boragineae incl. Cordiaceae (small knobs due to the hairs), Gesneraceae (walls of the hairs), Bignoniaceae (cells of the mesophyll), Acanthaceae (epidermis), Verbenaceae (small knobs due to the hairs), Aristolochiaceae (epid. cells + palisade-cells, cells of the mesophyll, Fig. 166, p. 684), Piperaceae (epidermis), Chloranthaceae (epidermis + cells of the mesophyll, cortex), Proteaceae (epidermis), Loranthaceae (cells of the mesophyll), Santalaceae (cells of the mesophyll), *Myzodendron* (cells of the mesophyll), *Champereia* (cells of the mesophyll), Euphorbiaceae (small knobs due to the hairs, epidermis), Urticaceae (small knobs due to the hairs, epidermis, cells of the mesophyll, fibrous cells of the bast).

There are far fewer records of the occurrence of **siliceous matter in the lumina of the cells** than of silicification of the cell-wall. The siliceous matter appears in the form either of silica-bodies, which lie freely in the lumina of the cells and arise freely in the protoplasm, or of silica-plugs; the latter are either formed freely in the protoplasm or are due to the apposition of siliceous matter upon the cell-wall, and ultimately fill the entire lumina of the cells.

To this category belong: the siliceous excretions, found in the mesophyll of certain Dilleniaceae and in the epidermis of the leaf of a member of the Magnoliaceae; the silica-bodies and silica-plugs in the cortex of *Eucommia* (Trochodendraceae); the silica-bodies in the mesophyll of species of *Meliosma* (Sabiaceae); the siliceous masses, filling (*a*) the sac-shaped cells found near the terminations of the veins in *Arcangelisia* (Menispermaceae), (*b*) some of the cells of the parenchyma accompanying the veins in *Ficus*, *Parartocarpus*, and *Sparattosyce* (Moraceae), and (*c*) the spicular cells of *Centraplacus* (Bixineae) and *Cynometra* (Caesalpinieae); the silica-bodies and silica-plugs, occurring in numerous Chrysobalaneae; the silica-bodies of the Podostemaceae (Fig. 163, p. 675); the silica-plugs in the hypoderm of the leaf of *Thottea* and *Apama* (Aristolochiaceae, Fig. 166, *H*, *J*, p. 684); the silica-bodies, found in the wood-parenchyma [2] in certain Dipterocarpeae, Malvaceae, Sterculiaceae, Tilia-

[1] For the occurrence of silica in cystoliths and cystolith-like structures, see § 28.
[2] Bargagli-Petrucci, in Malpighia, 1902.

ceae, Burseraceae, Anacardiaceae and Sapotaceae. Silica-plugs, moreover, appear to occur quite frequently in some of the cells composing cell-groups with silicified walls. The occurrence of silica-plugs in the vessels or other cells of the heart-wood has only been recorded in the plant from which 'cauto'-bark is obtained (Chrysobalaneae) and in some of the Verbenaceae; silica-plugs have been observed in intercellular spaces only in 'cauto'-bark.

§ 27. Carbonate of Lime. **Calcification of the cell-wall** is no common phenomenon. The parts chiefly affected are the walls of certain forms of hairs, which in these cases often have a verrucose surface (the most important being the 'cystolith-hairs'), and the cystoliths and cystolith-like structures (see § 28). Carbonate of lime, however, also occurs side by side with the silica in the walls of the small knobs, formed by the hairs of certain Compositae, &c. A feature deserving special mention is shown by the groups of enlarged epidermal cells, found in the leaf of *Hanburia* (Cucurbitaceae, see Fig. 86, p. 393); the common walls of contact between the cells are encrusted with carbonate of lime, while at the same time well-differentiated crystals of the same salt are deposited on the walls.

An incrustation of the cell-wall with carbonate of lime has been observed in the trichomes of the Cruciferae, Papilionaceae, Saxifragaceae (quite generally in the Philadelpheae and Hydrangeae), Loaseae, Cucurbitaceae, Umbelliferae, Cornaceae, Compositae, Campanulaceae, *Plocosperma*, Hydrophyllaceae, Boragineae, Scrophularineae, Gesneraceae, Verbenaceae and Urticaceae (Figs. 181 and 182, pp. 769 and 773).

In some woody plants **carbonate of lime** appears in **the form of cell-contents**, filling the vessels and other elements of the wood (especially of the heart-wood), as well as cells of the pith [1]. In order to avoid confusion with resinous substances, which very frequently block up the lumina of the vessels, it is necessary to apply the well-known reactions demonstrating the presence of carbonate of lime.

Carbonate of lime has been shown to occur in the wood or pith in the following Orders: Anonaceae, Zygophylleae, Aceraceae, Rosaceae, Cornaceae, Epacrideae, Sapotaceae, Urticaceae, Cupuliferae, Salicineae.

§ 28. Cystoliths and Structures Resembling Cystoliths [2]. Under **cystoliths** in the narrower sense only those protuberances of the cell-wall are understood, which, like the familiar cystoliths of *Ficus*, show differentiation into a stalk and a body. As a rule both carbonate of lime and silica play a part in the incrustation of the cystolith, the lime being deposited chiefly in and on the body, while the silica is mostly confined to the stalk and the nucleus of the cystolith. These structures are still described as cystoliths, when carbonate of lime is absent (uncalcified cystoliths, 'cystotyles' of Radlkofer), the body of the cystolith in such a case occasionally becoming suberized or lignified. They even remain cystoliths, when they consist throughout of silicified cellulose. We may at once note that these differences in the nature of the incrustation are of no very great systematic value, since cystoliths with and without incrustation, and cystoliths showing diverse types of incrustation may occur side by side even in one and the same species.

Cystoliths are found in the integumental tissue and mesophyll of the leaf and in the pith and cortex of the axis; they have not hitherto been observed in the wood. In the majority of cases they occur chiefly in the epidermis of the leaf, where they fill cells which are often of large size and

[1] See Molisch, in Sitz.-Ber. Wiener Akad., lxxxiv, Abt. 1, 1881.
[2] See especially Kohl, Kalksalze u. Kieselsäure, 1889, p. 115 et seq.

have a shape adapted to that of the cystolith; these cells penetrate into the inner tissues and mostly participate in the formation of the surface of the leaf only with a small part of their wall. At this point the stalk of the cystolith is generally attached; however, not uncommonly (Acanthaceae), the stalk appears to become resorbed secondarily. Well-developed cystoliths are occasionally found also in epidermal cells, which are differentiated as papillae or short hairs. The shape of the cystoliths varies, being spherical, ellipsoidal, fusiform, &c.; they are mostly unbranched, branched cystoliths being rare (certain Acanthaceae, Hernandiaceae and Urticaceae). The shape of the cystoliths can often be determined with the help of a lens, since in the dry leaf they frequently appear in the form of dots, striulae or small star-like structures. By the combination of two or more cystoliths or of the cells containing them ('lithocysts' of Radlkofer) there result the double cystoliths or groups of cystoliths, which occur in the Opilieae (Fig. 47, p. 203), in certain Cucurbitaceae (Fig. 85, p. 391) and Acanthaceae (Fig. 144, p. 615), and in *Champereia* (Fig. 179, p. 736). In these structures the stalks of the cystoliths are attached to the common wall of contact, or, in the case of groups of cystoliths, to the walls, which abut on one another.

Cystoliths have been observed in the Olacineae (all Opilieae, Fig. 47, p. 203), Cucurbitaceae (*Momordica* and *Coccinia*, Fig. 85, p. 391), Boragineae (*Tournefortia* and *Cordia*, Fig. 127, *A*, p. 559), Gesneraceae (*Klugia* and *Rhynchoglossum*)[1], Acanthaceae (very widely distributed, Fig. 144, p. 615; regarding blue cystoliths, see under Acanthaceae, p. 1019), Hernandiaceae (*Gyrocarpus* and *Sparattanthelium*, Fig. 172, p. 708), *Champereia* (only in the axis, Fig. 179, p. 736), and Urticaceae (certain Ulmaceae, Cannabineae, Moreae and Urticeae, Figs. 182 and 183, *A*, pp. 773 and 776).

The **structures resembling cystoliths** differ from true cystoliths in the fact that the stalk is absent, or at least not distinctly differentiated. As in the case of the typical cystoliths, the cystolith-like structures are encrusted either with carbonate of lime and silica, or only with the one or the other substance. Structures resembling cystoliths are, in the first place, found in trichomes, and are then known as **hair-cystoliths** (Figs. 82, 127, 181, *G*, and 182, pp. 379, 559, 769, 773). These hair-cystoliths either arise from the lateral wall at the base of the hair or form a continuation of the body of the hair, which is filled for a varying distance with caps of cellulose, the latter being either calcified or silicified, or both calcified and silicified. The differentiation of the hair-cystoliths shows an antagonistic relation between the development of hairs on the one hand and of cystoliths on the other, inasmuch as the greater the reduction in the length of the hair, the more strongly developed are the bodies of the cystoliths, and the more closely do they resemble the typical cystoliths (see Figs. 181, 182, pp. 769, 773). Papillose epidermal cells are frequently seen to contain typical cystoliths (see above). So that, whilst the hair-cystoliths on the one hand are connected by transitional forms with typical cystoliths, we find on the other hand all transitions from hair-cystoliths to hairs showing complete reduction of the bodies of the cystoliths, culminating in hairs, which are simply calcified. With the cystolith-like structures we may also class thickenings of the cell-wall (briefly described as protuberances in the synopsis, which follows below), which are found projecting in the form of humps into the lumina of the subsidiary cells of certain kinds of trichomes (the latter being calcified or silicified or provided with hair-cystoliths, Fig. 127, *C*, *D*, p. 559), and now and then also occur independently of the

[1] The structures, observed by Clarke (Hooker, Icones, Plate 1798, ed. 1888) in the leaf of the Gesneraceous species *Hemiboea Henryi*, Clarke and interpreted by him as cystoliths, are not cystoliths, but rod-shaped spicular cells, as I am able to state on the basis of a recent investigation.

hairs in groups of epidermal cells (see Fig. 85, p. 391) or in the ground tissue of the leaf (Fig. 179, p. 736); we may also include here the local peg-shaped thickenings found in certain species. The cystolith-like structures found in the subsidiary cells of the hairs arise from those parts of the walls which abut on the trichomes; the latter are invariably unicellular. The lithocysts form small knobs at the bases of the hairs, sometimes together with calcified and silicified cells devoid of cystolith-like structures (cf. § 26).

Structures resembling cystoliths have been observed in: Cistineae (species of *Cistus*, with silicified protuberances in epidermal cells, &c.[1]), Papilionaceae (species of *Cyamopsis* and *Indigofera*, with a calcified body resembling a cystolith in the terminal cells of the two-armed hairs), Mimoseae (protuberances in the subsidiary cells of the hairs, calcified in *Affonsea*), Samydaceae (*Homalium donquaiense*, with silicified protuberances in the mesophyll), Loaseae (hair-cystoliths, protuberances in the subsidiary cells of the hairs, Fig. 82, p. 379), Cucurbitaceae (as in the Loaseae, see also Fig. 85, p. 391), Compositae (calcified protuberances sometimes present in the subsidiary cells of the hairs), Campanulaceae (protuberances in reduced trichomes, in the epidermal cells of the margin of the leaf and in the subsidiary cells of the hairs, occasionally calcified), Myrsineae (protuberances in the epidermis of the leaf in *Clavija boliviensis*), Oleaceae (silicified protuberances in the subsidiary cells of the hairs of *Nyctanthes*), *Plocosperma* (calcified protuberances in the subsidiary cells of calcified hairs), Polemoniaceae (silicified protuberances in papillose epidermal cells and hair-cells), Hydrophyllaceae (hair-cystoliths and protuberances in subsidiary cells of the hairs, calcified), Boragineae (as in the previous case, Fig. 127, p. 559), Scrophularineae (hair-cystoliths and protuberances in the subsidiary cells of the hairs, calcified), Verbenaceae (as in the previous Order), Loranthaceae (silicified protuberances in the epidermis and mesophyll), Santalaceae (silicified protuberances in the ground tissue), *Champereia* (as in the previous case, Fig. 179, p. 736), Euphorbiaceae (silicified protuberances in the subsidiary cells of the hairs of *Bernardia*), Urticaceae (hair-cystoliths, protuberances, some of them peg-shaped, in the subsidiary cells of the hairs, and in epidermal cells, hypodermal cells and cells of the mesophyll, calcified or silicified, Figs. 181, 182, pp. 769, 773).

We may also include here the small peg-shaped structures arising from the outer walls of the epidermal cells in *Erythroxylon obtusum* (Lineae), and the peg-shaped bodies found in special epidermal cells in the leaf of *Anamirta* and *Arcangelisia* (Menispermaceae), the cells in question functioning as hydathodes.

Quite a special form of the structures resembling cystoliths is constituted by the uncalcified **cystotyles** and **cystospheres**, which occur in certain Begoniaceae, and are arranged in pairs after the manner of the double cystoliths; they have an approximately hemispherical shape and are inserted on the common wall of contact between their lithocysts by means of a small, scarcely marked stalk. The cystotyles of the Begoniaceae are distinguished by the fact that they consist of a mucilaginous ground-substance, which after treatment with alcohol shows concentric stratification and radial striation, while in some of the cystotyles the ground-mass is impregnated with a resinous substance. The distinctive character of the cystospheres lies in their being composed of a mass of secretion, which is enclosed in a kind of sac; for details see pp. 402, 403, and Fig. 87. The cystospheres are closely related to the secretory cells of certain Magnoliaceae, Canellaceae, &c., in which the secretion is enclosed in a peculiar pouch; cf. § 14, p. 1096.

We may mention the following facts regarding the **systematic importance of the cystoliths and cystolith-like structures**. The cystoliths in the strict sense have proved to be of most value, for they occur only in a few Orders and are characteristic of whole tribes or genera. How far the shape and position of the cystoliths can be employed for taxonomic purposes is shown

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[1] According to Gard, in Comptes rendus Acad. Paris, cxlv, 1907.

especially by the systematic papers dealing with the cystoliths of the Acanthaceae and Urticaceae. The cystotyles and cystospheres of the Begoniaceae are not of general occurrence throughout the Order, but are often characteristic of certain sections of the genus *Begonia*. Data as to the extent to which the cystolith-like structures can be employed in distinguishing species are contained chiefly in Mez's and Priemer's papers, which deal with the cystoliths of the Cordiaceae and Ulmaceae respectively.

IV. Hairy Covering[1].

§ 29. General Review. In this chapter I propose to deal both with the clothing hairs (§§ 30–33) and the glandular hairs (§ 34); in addition, we may append to our discussion of the latter a consideration of glandular leaf-teeth (§ 35), large glandular mechanisms, which mostly excrete nectar and are therefore generally described as extrafloral nectaries (§ 36), the lime- and salt-glands of the Frankeniaceae, Tamariscineae, and Plumbagineae (§ 37), and special forms of glands found in insectivorous plants (§ 38).

As is well known, clothing and glandular hairs are distinguished from one another by the absence and presence respectively of secretion. The product of the secretion is, however, not always of an oily, resinous or mucilaginous nature, but may sometimes (in the case of hydathodes) be nothing but water, nor does the process of secretion always continue throughout the life of the plant; very often, moreover, the plants are only available for investigation in the form of herbarium-material. Under these circumstances the recognition of a trichome as a clothing or glandular hair would be attended with difficulties were it not for the fact that the glandular hairs are in almost all cases distinguished morphologically as well as by their function, inasmuch as the upper secreting portion is more or less sharply marked off (frequently in the form of a head) from a basal portion resembling a stalk, or at least has thinner walls than the basal portion. When a systematic anatomical investigation is being undertaken on herbarium-material, it is necessary to pay special attention to these features. In some cases living material is indispensable, if the nature of a trichome is to be properly determined.

The **systematic value of the hairy covering** is very great. In the first place the presence or absence of glandular hairs affords an important feature, which is sometimes characteristic of entire Orders, while in other Orders it only serves to distinguish genera or species. In the second place the morphological structure of the hairs is to be taken into consideration. As regards the clothing hairs, a first point of great importance is whether they are unicellular or uniseriate. Although these two forms of hairs are not at all uncommonly found side by side in the same species (often even on the same organ of the plant), in certain Orders we find that without exception, or almost without exception, only unicellular or only uniseriate hairs are present either on all the organs of the plant or at least on the vegetative organs. In the Papilionaceae and Compositae, for instance, nearly all the clothing hairs hitherto observed are uniseriate, while in the Cruciferae only unicellular clothing hairs have been recorded. In the case of multicellular glandular hairs, a feature which is quite especially valuable for taxonomic purposes has been shown to lie in the mode of division of the head; in some cases the head is divided

[1] See A. Weiss, Pflanzenh., Berlin, 1867, also in Karsten, Bot. Untersuch., Bd. 1; Martinet, in Ann. sc. nat., sér. 5, t. xiv, 1872; De Bary, Vergl. Anat., 1877; Theorin, Växttrichom., Archiv för Bot., i, iii, and iv, 1903–5; Hirsch, Untersuch. über d. Entwickl. d. Haare bei den Pfl., Diss., Berlin, 1899, 41 pp., also in Fünfstück, Beitr., iv.

exclusively by means of vertical walls, while in other cases the division-walls are horizontal, or both horizontal and vertical. In this way, for example, it is possible to distinguish the Scrophularineae from the Solanaceae, since the Scrophularineae have glandular hairs of the first type, while the Solanaceae have those of the second type. In the third place an abundance of useful characters, serving to distinguish taxonomic groups of varying magnitude down to species, is afforded by the numerous modifications in the form and size of the hairs; in the case of the clothing hairs similar characters are provided by the shape of the cells composing the hairs, as well as by the nature of their walls and lumina, and, in the case of the glandular hairs, by the structure of the secreting portion and stalk, and the localization and nature of the secretion.

In some Orders, genera, and species only one form of hair is found, but in other cases two or more types of hairs are present. In the latter case a certain definite plan of structure frequently reappears in all the different forms of hairs belonging to the same Order (see Cruciferae, Droseraceae, Loganiaceae-Buddleioideae, Convolvulaceae, &c.), genus or species.

In investigating the hairy covering with a view to its employment for systematic purposes it is advisable to make the investigation a comparative one, and, wherever possible, always to examine the same organs of the plant, viz. in the first place the leaf, then the axis, and only as a last resort (namely, when no trichomes are to be found on the vegetative organs) the reproductive organs [1].

§ 30. Classification of the Clothing Hairs. The typical forms of clothing hairs may be distinguished as follows:—I. **Simple clothing hairs** or briefly hairs, which are formed by a single cell (not developed as a flat structure), or by a row of two or more cells. II. **Peltate hairs,** scales or lepides, i.e. sessile or stalked structures, which consist in the main either of a single cell, developed as a flat surface (in the formation of which the stalk may participate), or of a varying number of cells arranged in one or more layers; with the peltate hairs we may associate the **stellate** and **candelabra-hairs,** discussed in §§ 31 and 32. III. **Shaggy hairs,** i.e. filiform structures, the base of which at least consists of two or more rows of cells, such hairs being either of epidermal origin or of the nature of emergences; and with them we may class **warts** and **spines,** i.e. massive multicellular structures, which either have blunt or pointed ends and are likewise partly of the nature of emergences.

§ 31. Simple Clothing Hairs. This section first contains a synopsis of the distribution of the ordinary (mostly filiform) unicellular and uniseriate clothing hairs in the different Orders; unicellular hairs, which show a vesicular or papillose differentiation, are summarized under a separate heading. It is impossible to enter into details here regarding the manifold individual differences in structure shown by the simple clothing hairs (already in part referred to in § 29); these differences, which concern the length, shape, and structure of the walls and lumina of the cells composing the hairs, and (more especially as regards the uniseriate trichomes) also the structure and position of the division-walls and the mode of demarcation of the cells, can all be employed for systematic purposes, when their constancy has been sufficiently established. Only a few forms of hairs, which are quite particularly noteworthy (e.g. especially bracket-hairs, two- and one-armed hairs, and branched

[1] The hairs (and especially the glandular hairs), found in the floral region, occasionally show a reduced form or even an altered plan of structure as compared with the hairs present on the leaves of the same species; see, for instance, under Verbenaceae, p. 1021.

hairs of the stellate and candelabra-types, which can be derived from unicellular and uniseriate hairs), will be considered in greater detail and with special reference to their distribution.

I. **Unicellular clothing hairs of a papillose or vesicular type** (cf. also § 2, p. 1076) have been observed in the: Resedaceae, Fumariaceae, Caryophylleae, Portulaceae, Geraniaceae, Celastrineae, Hippocrateaceae, Rhamneae, Aceraceae, Coriarieae, Papilionaceae (rare and only occurring in those species, which have a papillose epidermis), Crassulaceae (Fig. 70, *B*, *C*, p. 321), Halorageae, Melastomaceae, Lythrarieae, Ficoideae, Umbelliferae, Rubiaceae, Campanulaceae, Loganiaceae, Gentianeae, Polemoniaceae, Plantagineae, Illecebraceae, Amarantaceae, and Moraceae. For the development of ordinary papillae on the epidermis, see § 1, p. 1073.

II. **Ordinary unicellular clothing hairs**[1] **of greater length** have been observed in: Ranunculaceae (Fig. 1, p. 16, see also III), Dilleniaceae, Calycanthaceae (Fig. 3, p. 25), Magnoliaceae (see III), Trochodendraceae (see III), Anonaceae (see III), Menispermaceae (see III), Berberideae (see III), Sarraceniaceae, Cruciferae (Fig. 15, p. 63), Capparideae (Fig. 19, p. 75, see III), Resedaceae, Cistineae (Fig. 21, p. 81), Violarieae (see III), Bixineae (see III), Tremandreae, Polygaleae (see III), Vochysiaceae, Frankeniaceae, Portulaceae, Tamariscineae, Elatineae (see III), Hypericineae (see III), Guttiferae (see III), Ternstroemiaceae (see III), Dipterocarpeae, *Monotes*, Chlaenaceae, Malvaceae (see III), Sterculiaceae (see III), Tiliaceae (see III), Rhaptopetalaceae, Lineae, Humiriaceae (see III), Zygophylleae (Fig. 38, p. 168), Geraniaceae (see III), Rutaceae (see III), Simarubaceae (see III), *Koeberlinia*, *Balanites*, Ochnaceae (see III), Burseraceae (see III), Meliaceae (see III), Chailletiaceae (Fig. 46, p. 198), Olacineae (see III), Ilicineae (see III), Celastrineae (see III), Pentaphylacaceae, Stackhousieae, Rhamneae (see III), Ampelidaceae (see III), Sapindaceae (see III), Hippocastanaceae (see III), Aceraceae (see III), Staphyleaceae, Sabiaceae (see III), Anacardiaceae (see III), Moringeae, Connaraceae, Caesalpinieae (see III), Mimoseae (see III) Rosaceae, Saxifragaceae (see III), Droseraceae, Hamamelideae, Bruniaceae, Halorageae (see III, Gunneroideae, Schindl.), Rhizophoraceae, Combretaceae (Fig. 76, p. 346), Myrtaceae (sens. str.), Lecythidaceae (see III), Melastomaceae (rare, see III), Lythrarieae (see III), Onagrarieae (see III), Samydaceae (see III), Loaseae (Fig. 82, p. 379, see III), Turneraceae (see III), Passifloraceae (see III), Cucurbitaceae (see III), Cacteae (see III), Ficoideae, Umbelliferae (see III), Cornaceae, Caprifoliaceae, Rubiaceae (Fig. 101, p. 446, see III), Valerianeae (see III), Dipsaceae, Candolleaceae, Goodeniaceae (see III), Campanulaceae (see III), Lobeliaceae (see III), Vacciniaceae (see III), Ericaceae (see III), Monotropeae, Epacrideae (see III), Diapensiaceae, Plumbagineae, Sapotaceae (*Delpydora*), Ebenaceae, Oleaceae (see III), Salvadoraceae, Apocynaceae (see III), Asclepiadeae (see III), Loganiaceae (see III), *Plocosperma*, Gentianeae (see III), Polemoniaceae (see III), Hydrophyllaceae (see III), Boragineae (Fig. 127, p. 559, see III), Cuscuteae (see III), Nolaneae (see III), Solanaceae (rare, see III), Scrophularineae (see III), Orobanchaceae (see III), Columelliaceae, Bignoniaceae (see III), Pedalineae (see III), Acanthaceae (see III), Verbenaceae (see III), Labiatae (see III), Illecebraceae (see III), Amarantaceae (see III), Chenopodiaceae (very rare, see III), Polygonaceae (see III), Myristicaceae, Monimiaceae, Laurineae, Hernandiaceae, Proteaceae (see III), Thymelaeaceae, *Octolepis*, *Gonystylus*, Penaeaceae, *Geissoloma*, Santalaceae (see III), *Myzodendron*, *Grubbia*, Balanophoreae, Euphorbiaceae (see III), Buxaceae (see III), Ulmaceae (mostly, see III), Cannabineae (see III), Moraceae (see III), Urticeae, Thelygoneae, Juglandeae, Myricaceae (see III), Cupuliferae (see III), Salicineae, Lacistemaceae (see III), Empetraceae, Ceratophylleae; unicellular clothing hairs, but showing a special type of structure throughout (see p. 1117 et seq.), are found also in the Orders Malpighiaceae, Papilionaceae, Compositae, Sapotaceae (excl. *Delpydora*) and Styraceae.

III. **Ordinary simple uniseriate clothing hairs** or trichomes differing but little from the ordinary type (see p. 1118 under trichomes with long terminal cells) have been observed in: Ranunculaceae (see also II), Magnoliaceae (see II), Trochodendraceae (see II), Anonaceae (see II), Menispermaceae (see II), Berberideae (see II), Nymphaeaceae, Papaveraceae, Capparideae (see II), Violarieae (see II), Bixineae (see II), Pittosporeae (Fig. 22, p. 93), Polygaleae (see II), Caryophylleae, Elatineae (see

[1] The figures cited under II and III in part refer to special forms of unicellular or uniseriate clothing hairs (see p. 1117 et seq.).

II), Hypericineae (see II), Guttiferae (Fig. 28, p. 123, see II), Ternstroemiaceae (see II), Malvaceae (see II), Sterculiaceae (see II), Tiliaceae (see II), Humiriaceae (see II), Geraniaceae (see II), Rutaceae (see II), Simarubaceae (see II), Ochnaceae (see II), Burseraceae (see II), Meliaceae (see II), Olacineae ? (see II), Ilicineae (see II), Celastrineae (see II), Hippocrateaceae (see I), Rhamneae (see II), Ampelidaceae (see II), Sapindaceae (see II), Hippocastanaceae (see II), Aceraceae (see II), Sabiaceae (see II), Anacardiaceae (see II), Papilionaceae (rare, Fig. 59, p. 268), Caesalpinieae (rare, see II), Mimoseae (very rare, see II), Saxifragaceae (see II), Halorageae (see II, Haloragoideae, Schindl.), Lecythidaceae (see II), Melastomaceae (rare, see II), Lythrarieae (see II), Onagrarieae (see II), Samydaceae (see II), Loaseae (see II), Turneraceae (see II), Passifloraceae (see II), Cucurbitaceae (see II), Begoniaceae, Cacteae (see II), Umbelliferae (see II), Araliaceae, Rubiaceae (see II), Valerianeae (see II), Compositae, Goodeniaceae (see II), Campanulaceae (rare, see II), Lobeliaceae (see II), Vacciniaceae (see II), Ericaceae (see II), Epacrideae (see II), Primulaceae (Fig. 114, p. 502), Myrsineae, Styraceae, Oleaceae (see II), Apocynaceae (Fig. 121, p. 530, see II), Asclepiadeae (see II), Loganiaceae (see II), Gentianeae (see II), Polemoniaceae (see II), Hydrophyllaceae (see II), Boragineae (see II), Convolvulaceae (Fig. 129, p. 567), Cuscuteae (see II), Nolaneae (see II), Solanaceae (see II), *Retzia*, Scrophularineae (see II), Orobanchaceae (see II), Lentibularieae, Gesneraceae (Fig. 140, p. 599), Bignoniaceae (see II), Pedalineae (see II), Acanthaceae (see II), Myoporineae, *Zombiana*, Selagineae, Verbenaceae (see II), Labiatae (see II), Plantagineae (Fig. 153, p. 643), Nyctagineae, Illecebraceae (see II), Amarantaceae (Fig. 156, p. 652, see II), Chenopodiaceae (Fig. 159, p. 659, see II), Polygonaceae (see II), Phytolaccaceae, Nepenthaceae (Fig. 165, p. 679), Aristolochiaceae (Fig. 166, p. 684), Piperaceae, Proteaceae (Fig. 173, p. 713, see II), Santalaceae (see II), Euphorbiaceae (see II), Buxaceae (see II), Ulmaceae (rare, see II), Cannabineae (see II), Moraceae (see II), Leitnerieae, Myricaceae (see II), Casuarineae (Fig. 186, p. 788), Cupuliferae (see II), Lacistemaceae (see II); uniseriate clothing hairs, which are, however, distinguished by a special shape (see p. 1118 et seq.), occur also in the Chlaenaceae, Connaraceae, Caesalpinieae, Cornaceae, Myristicaceae and Loranthaceae.

The following lines in the first place contain an enumeration of the **special forms of unicellular hairs**, which require mention; these hairs are distinguished by their shape, their size, the structure of their wall or their contents. Very small silicified trichomes, which are inserted in the outer wall of the epidermis, are found in *Petraea* (Verbenaceae, Fig. 151, *A*, *B*, p. 632); small silicified trichomes resembling papillae occur in certain Moraceae; short hairs, provided with a spherical base showing spiral thickening, in certain Sapindaceae, and hairs having a similar structure in a certain species of *Zizyphus* (Rhamnaceae) and in species of *Artocarpus* (Moraceae); short unicellular laticiferous hairs, which enter into connexion with the laticiferous system, in some Cichoriaceae (Fig. 103, *O*, p. 458); small capitate hairs with a spherical or pyriform (glandular?) head in *Cardiopteris* and *Platea* (Olacineae, Fig. 48, *B*, *C*, p. 204) and hairs having a similar structure in *Symplocos* (Styraceae); small trichomes, shaped like a clustered crystal, in *Peixotoa* (Malpighiaceae, Fig. 36, p. 164); longer trichomes, the apex of which is bent in the form of a hook (**bracket-hairs**, climbing hairs, or hooked hairs, see Fig. 182, *D*, p. 773), in certain Bixineae, Burseraceae, Caesalpinieae, Mimoseae, Passifloraceae, Rubiaceae, Boragineae, Labiatae, *Circaeaster* (only on the fruit), Hernandiaceae, Moraceae, and Urticeae, and short hairs, shaped like an angler's hook, in certain Cornaceae (Fig. 99, *G*, p. 435); anchor-hairs and trichomes, provided with spines, which are directed either forwards or backwards, in the Loaseae (Fig. 82, p. 379). At this point we may also mention the following types of hairs: the **two-armed hairs** (the arms being of equal or of unequal length), found in certain Cruciferae (Fig. 15, *C*, p. 63), Capparideae (Fig. 19, *B*, p. 75), Vochysiaceae, Ternstroemiaceae (*Microsemma* ?), Chlaenaceae, Malpighiaceae (of almost constant occurrence, Fig. 36, p. 164), Zygophylleae, Simarubaceae, Burseraceae (Fig. 43, *E*, p. 191), Meliaceae, Celastrineae, Ampelidaceae, Connaraceae (Fig. 55, *A–C*, p. 252), Caesalpinieae, Rosaceae, Combretaceae, Myrtaceae sens. str., Lythrarieae

(*Cuphea* pro parte! Fig. 80, *C*, p. 370), Samydaceae (*Banara, Homalium ?*), Ficoideae, Cornaceae (Fig. 99, *B*, p. 435), Sapotaceae (almost constant, in part glandular), Boragineae, Acanthaceae, Verbenaceae, Monimiaceae, Hernandiaceae (only in *Illigera obtusa*), Thymelaeaceae, Euphorbiaceae and Cannabineae (Fig. 181, p. 769); **the one-armed hairs** (which sometimes show transitions to two-armed hairs, while in other cases they are merely provided with a faint crop-like protrusion on one side of the stalk), occurring in certain Vochysiaceae, Malpighiaceae (Fig. 36, *E*, p. 164), Zygophylleae, Meliaceae, Celastrineae, Sapindaceae, Connaraceae, Mimoseae, Saxifragaceae, Combretaceae, Myrtaceae sens. str., Sapotaceae, Ebenaceae, Boragineae (Fig. 126, *D*, p. 557), Acanthaceae and Laurineae; the **stellate hairs** present in certain Cruciferae (Fig. 15, *D*, *E*, p. 63), Capparideae (Fig. 19, *C*, p. 75), Ternstroemiaceae (Fig. 30, *B*, p. 133; in this Order the stalk is sometimes demarcated, while the shield is now and then provided with a division-wall) and Saxifragaceae (Fig. 68, *B*, *C*, p. 316); the **peltate hairs**, occurring in certain Cruciferae (Fig. 15, *F*, p. 63); and the dendroid hairs, found in certain Cruciferae (Fig. 15, *G*, p. 63), Papilionaceae (*Dipteryx*, Fig. 59, *F*, p. 268) and Boragineae (*Cordia*, Fig. 126, *C*, p. 557). A kind of doubling of the unicellular body of the hair in the longitudinal direction owing to the formation of a cap of cellulose is found in the Cistineae (Fig. 21, *A*, p. 81), Combretaceae (Fig. 76, *A*, *B*, p. 346), and Myrtaceae sens. str. The following hairs are distinguished by having special contents: the **stinging hairs** of the Loaseae, Euphorbiaceae and Urticeae (Fig. 183, p. 776), these hairs being occasionally inserted on a pedestal composed of a large number of cells; the **crystal-containing hairs** of certain Euphorbiaceae (Fig. 180, *R*, *S*, p. 748)[1], which are differentiated as papillae and enclose either a clustered crystal or a sphaerite; the stinging hairs of certain Euphorbiaceae, which are occasionally situated on a pedestal resembling a shaggy hair, and contain an acicular crystal of oxalate of lime, suspended in the cavity of the cell by means of beams of cellulose (Fig. 180, *P*, *Q*, p. 748)[1]; and the crystal-hairs (Fig. 101, *B*, *C*, p. 446) of the Guettardeae (a tribe of the Rubiaceae), which are paved with one or more rows of small crystals of oxalate of lime. The formation of more or less distinct papillae on the walls of the hairs, in which case the lumina of the hairs may or may not penetrate into the papillae, has been recorded in the unicellular trichomes of certain Cruciferae, Bixineae, Geraniaceae, Chailletiaceae (Fig. 46, p. 198), Rosaceae, Saxifragaceae (Fig. 68, *A*, p. 316) and Cornaceae. Regarding calcification of the cell-wall in unicellular hairs and regarding cystolith-hairs, see §§ 27 and 28.

The following noteworthy **modifications of uniseriate trichomes** may be mentioned. The uniseriate clothing hairs are sometimes characterized by the fact that the lower or lowest cells of the hair are short, while the terminal cell is long and forms the greater part of the trichome. Such **trichomes with long terminal cells** have been observed in the following Orders: Magnoliaceae, Trochodendraceae, Anonaceae, Menispermaceae, Berberideae, Nymphaeaceae, Pittosporeae (Fig. 22, *B*, p. 93), Caryophylleae, Sabiaceae, Papilionaceae (Fig. 59, *A*–*C*, p. 268), Caesalpinieae (very rare), Umbelliferae, Compositae (Fig. 103, *A*, *B*, p. 458), Polemoniaceae, Boragineae, Convolvulaceae (in all the members of the Order! Fig. 129, *A*, p. 567), Solanaceae, *Retzia*, Acanthaceae, Verbenaceae, Labiatae, Plantagineae, Amarantaceae, Chenopodiaceae, Aristolochiaceae, Proteaceae (Fig. 173, *E*, p. 713), Casuarineae (Fig. 186, *E*, p. 788). **Uniseriate hairs**

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[1] It may be pointed out in passing that the crystal-hairs and stinging hairs mentioned above as occurring in certain Euphorbiaceae, although they appear like trichomes, are *not hairs* in the strict sense (i. e. *according to a scientific interpretation of their morphology*), inasmuch as they arise from subepidermal and not from epidermal cells; only secondarily do they push their way between the epidermal cells, thus ultimately extending beyond the level of the epidermis. For details, see under Euphorbiaceae, p. 1051.

with a capitate terminal cell, which, however, has no secretory function, have been observed in many Amarantaceae and Chenopodiaceae (Fig. 159, *C*, p. 659), as well as in certain Papaveraceae, Compositae (Fig. 103, *E*, p. 458), Nyctagineae (here glandular? Fig. 154, *A*, p. 646) and Illecebraceae. Other specially noteworthy forms are constituted by the urn-shaped trichomes and the paired uniseriate hairs, with fused basal portions, found in species of *Gilia* (Polemoniaceae), and the uniseriate hairs with a sunken basal portion, divided by closely placed transverse septa, occurring in certain Hippocrateaceae and Polemoniaceae. The unicellular bracket-hairs, two-armed hairs, stellate and peltate hairs find their equivalents in uniseriate trichomes, in which the terminal cell shows a corresponding shape. **Uniseriate trichomes with a terminal cell bent in the form of a hook** are found in certain Papilionaceae, Gesneraceae, Verbenaceae and Aristolochiaceae (Fig. 166, *K*, p. 684; in the Order last named the cells of the stalk occasionally also show division-walls running parallel to the length of the hair); **two-armed hairs**, in which the stalk is unicellular or uniseriate, and the terminal portion for the most part unicellular, occur in certain Pittosporeae (Fig. 22, *A*, p. 93), Rhamneae, Aceraceae, Papilionaceae, Caesalpinieae, Saxifragaceae, Araliaceae, Cornaceae (Fig. 99, *D*, p. 435), Compositae (Fig. 103, *F*, p. 458), Boragineae (Fig. 126, *E*, p. 557; in *Cordia* the two arms are occasionally septate), Convolvulaceae (Fig. 129, *B*, *C*, p. 567; occasionally one-armed, the long arm being septate), Amarantaceae (Fig. 156, *F*, p. 652), Chenopodiaceae (Fig. 159, *B*, p. 659), Myristicaceae and Proteaceae (Fig. 173, *F*, p. 713); **uniseriate trichomes with a stellate or peltate terminal cell** are found in certain Chlaenaceae (Fig. 33, p. 145), Papilionaceae (Fig. 59, *E*, p. 268), Ficoideae (Fig. 94, *C*, p. 416), Compositae (Fig. 103, *D*, p. 458), Convolvulaceae (Fig. 129, *F*, *G*, p. 567), Amarantaceae (in *Iresine* the terminal cell shows transitions to a two-armed differentiation, Fig. 156, *E*, p. 652), Chenopodiaceae (Fig. 159, *G*, *H*, p. 659) and Loranthaceae (?). With the trichomes last mentioned we may class **uniseriate candelabra-hairs**, in which the individual tiers are composed either of two-armed cells—the arms of which point in different directions (*Dampiera*, Goodeniaceae, Fig. 106, p. 471) or lie in the same vertical plane (Myristicaceae, Fig. 170, *D–F*, p. 698)—or of cells, developed after the manner of a stellate hair (Compositae, Amarantaceae, Fig. 156, *D*, p. 652, Loranthaceae, Fig. 177, *C–E*, p. 728). Uniseriate hairs, in which the division-walls are oblique, while the ends of some or all of the component cells are drawn out into lateral papillae, or, in other words, push their way laterally along the basal portion of the cell immediately above, are found in certain Polemoniaceae, Plantagineae (Fig. 153, p. 643), Nepenthaceae (Fig. 165), and Loranthaceae (Fig. 177, *B*, p. 728); such hairs constitute transitions to trichomes with sympodial structure (see below). **Multicellular hairs**, which vary in shape and are **branched in a dendroid or dichotomous manner**, have been observed in the Orders Guttiferae (Fig. 28, p. 123), Ternstroemiaceae (Fig. 30, *A*, p. 133), Olacineae (Fig. 48, *A*, p. 204), Lecythidaceae, Melastomaceae, Lythrarieae, Araliaceae, Campanulaceae, Primulaceae (Fig. 114, *A*, p. 502), Myrsineae, Apocynaceae (Fig. 121, *B*, p. 530), Loganiaceae, Polemoniaceae, Boragineae (Fig. 126, *B*, p. 557), Nolaneae (Fig. 132, p. 574), Solanaceae (Fig. 133, p. 577), Scrophularineae, Gesneraceae, Bignoniaceae (Fig. 141, *A*, p. 603), Myoporineae, Verbenaceae, Labiatae (Fig. 152, p. 638), Nyctagineae (Fig. 154, *B*, p. 646, glandular ?), Illecebraceae, Amarantaceae, Euphorbiaceae (rare) and Casuarineae; it is possible to derive such hairs from uniseriate trichomes by assuming a protrusion of the component cells into branches, demarcation of these branches, and the appearance of division-walls in them, this being followed by the protrusion of branches of the second Order, and so on. Special forms of these trichomes are constituted by the peculiar hairs of *Jacquinia* (Myrsineae, Fig. 116, *C*, p. 510) and by branched or tufted hairs, which in typical cases consist of flattened cells, each of which is

protruded to form a single branch (i.e. the component cells are one-armed). Since the axial portion of such trichomes shows a sympodial relation to the branches, they may be described as **sympodially branched hairs**; they are more or less markedly differentiated in certain Caryophylleae, Celastrineae (very faintly indicated), Connaraceae (Fig. 55, *D–F*, p. 252), Bignoniaceae, Myoporineae, Nepenthaceae (Fig. 165, *C*, p. 679), Myristicaceae (Fig. 170, p. 698), and Casuarineae (Fig. 186, *D*, p. 788). A brief reference may still be made to the manifold transitions between branched trichomes, derived from uniseriate hairs, and the trichomes dealt with in the following paragraphs. The wall of the uniseriate trichomes, as in the case of the unicellular hairs, is occasionally (Papilionaceae,—here the wall of the terminal cell,—Polemoniaceae, Amarantaceae, Fig. 156, p. 652, and Chenopodiaceae, Fig. 159, p. 659) provided with small papillose protrusions, while in certain Compositae (Fig. 103, *C*, p. 458), Plantagineae (Fig. 153, *B*, p. 643), and Amarantaceae (Fig. 156, *C*, p. 652) *the upper ends of the cells composing the hairs bear papillose processes*, which establish a firm connexion between the cells. Regarding calcification of the walls of the hairs, see § 27.

§ 32. Peltate, Stellate and Candelabra-Hairs. In this section our summary will be confined to those peltate, stellate and candelabra-hairs, in which the shield, stellate portion and radiating tiers respectively are composed of two or more cells. Peltate and stellate hairs, which with or without the stalk consist of a single cell, and candelabra-hairs, the tiers of which are composed of single cells drawn out into rays, have already been dealt with in § 31.

The three forms of hairs in question are very closely related to one another. From a stellate hair, in which the ray-cells are spread out horizontally, we can derive a peltate hair by the coalescence of the ray-cells, while a candelabra-hair is obtained by the repeated development of ray-cells (and sometimes of stalk-cells as well) in the longitudinal direction. We accordingly find that stellate and peltate hairs, or stellate and candelabra-hairs, not uncommonly occur side by side with one another in the same taxonomic group or even in the same species; in such cases the two forms of hairs may show the same special type of structure, while transitional forms between them are of frequent occurrence.

The **peltate hairs**[1] (the delimitation of which from the peltate glands dealt with under I in § 34 occasionally—when an investigation of living material is impossible—presents some difficulties) show a very diverse structure, and the differences can be employed for systematic purposes in the same way as the presence or absence of these trichomes; the latter are sometimes (Elaeagnaceae) of constant occurrence throughout an Order, although generally confined to certain species. The differences in the structure of the peltate hairs are afforded either by the shield or by the stalk. The former for the most part consists of a single layer of cells and varies in size. In the ordinary and most widely distributed type of peltate hairs the shield is composed of radially arranged cells, of which all or only some reach the centre of the shield; these ray-cells have walls of varying thickness and mostly project at the margin of the shield in the form of short rays. In other cases the shield has an entire margin, the ray-cells being broadened towards the outside in the shape of a wedge. The shield presents still a different appearance, when the radially arranged ray-cells undergo tangential divisions. If irregular divisions follow the appearance of the first radial division-walls, the shield seems to be composed of polygonal cells, when seen in surface-view. In the following cases the shield shows quite a special type of structure. In certain Buddleioideae

[1] See O. Bachmann, Schildhaare, Flora, 1886.

(Fig. 124, p. 542) we find peltate hairs with a bicellular shield. In the species of *Solanum* (Fig. 133, p. 577) a spherical or otherwise shaped cell is seated on the centre of the shield of the peltate hairs, which in other respects show the ordinary type of structure; in certain Capparideae (Fig. 19, p. 75), Malvaceae and Sterculiaceae there is a so-called 'upper scale' in the form of a rosette of small cells, while in certain species of *Croton* (Fig. 180, p. 748) a similar rosette of small cells is situated beneath the shield, constituting a so-called 'lower scale,' the shield in the latter case being provided with a central cell. In certain species of *Miconia* (Melastomaceae) there is a small upper scale composed of short ray-cells, and in some cases also a small lower scale. A doubling of the shield in the radial direction is found in *Phebalium* (Rutaceae, Fig. 41, p. 177) and in certain Bombaceae (Malvaceae, Fig. 34, p. 149): in these cases most of the cells extending outwards from the centre of the shield stop short of the margin, while those forming the margin do not reach the centre, so that the marginal cells constitute, as it were, a duplication of the central cells, which in themselves are already united to form a scale. It remains to mention the peltate hairs of *Clerodendron* (Verbenaceae, Fig. 151, p. 632), in which the shield is composed of several layers of cells showing a polygonal outline, when seen from the surface. The stalk of the peltate hairs is formed either by a single cell or by a row of cells, or by a multiseriate complex of cells, its length often varying very considerably on the surface of one and the same organ; in some cases (Dilleniaceae, Loganiaceae, Euphorbiaceae pro parte) the cells of the shield are themselves either exclusively or partially concerned in the formation of the stalk.

Peltate hairs with a shield, composed of two or more cells, have been observed in the following Orders and genera respectively: Dilleniaceae (Fig. 2, p. 22), Anonaceae (Fig. 6, p. 36), Capparideae (Fig. 19, p. 75), Cistineae (Fig. 21, p. 81), Bixineae, Malvaceae (Fig. 34, p. 149), Sterculiaceae (Fig. 35, p. 154), Tiliaceae, Rutaceae (Fig. 41, p. 177), Burseraceae (*Zanha*, Hiern), Meliaceae (Fig. 45, p. 197), Olacineae (Fig. 48, p. 204), Rosaceae, Halorageae (Fig. 72, p. 337, *Callitriche*, *Hippuris*), Melastomaceae, Begoniaceae, Datisceae, Araliaceae (Fig. 98, p. 429), Caprifoliaceae (Fig. 100, p. 441), Ericaceae (Fig. 110, p. 485), Myrsineae (Fig. 116, p. 510), Styraceae, Oleaceae (Fig. 119, p. 523), Salvadoraceae (in this Order there is only a tendency to form small scales, Fig. 120, p. 527), Loganiaceae (Buddleioideae, Fig. 124, p. 542), Solanaceae (Fig. 133, p. 577), Verbenaceae (Fig. 151, p. 632), Monimiaceae (Fig. 171, p. 701), Elaeagnaceae (Fig. 176, p. 725), Euphorbiaceae (Fig. 180, p. 748), Cupuliferae (Fig. 187, p. 793). For glandular peltate hairs, see under I b in § 34, p. 1128.

The **stellate hairs**, according to the direction of their rays, which generally consist of single cells, are either stellate hairs in the narrow sense or tufted hairs; in the former case the rays are spread out in a plane, which is roughly parallel to the surface of the organ, while in the case of the **tufted hairs** the rays diverge in various directions or are all placed approximately at right angles to the surface. In the simplest case, the ray-portion, consisting of unicellular rays, is sunk directly in the epidermis, so that the trichome is formed merely by a group of epidermal cells, developed as hairs; the neighbouring epidermal cells are frequently prolonged into the body of the hair, thus forming a pedestal of varying height. In other cases the rays are borne on a stalk, which varies in length, and is composed of one or more rows of cells; it occasionally resembles a shaggy hair. The rays are rarely uniseriate. Other differences in the structure of the stellate hairs, which can be employed for systematic purposes, are found in the length and number of the rays, and in the nature of their walls and lumina. A considerable number of transitions have been observed between the branched multicellular hairs, dealt with in § 31 (p. 1119) and the hairs under discussion.

Stellate hairs have been met with in the following Orders and genera respectively: Dilleniaceae (Fig. 2, p. 22), Magnoliaceae ?, Anonaceae, Capparideae (Fig. 19, p. 75), Cistineae (Fig. 21, p. 81), Bixineae, Tremandreae, Vochysiaceae, Frankenia-

ceae, Hypericineae, Ternstroemiaceae (Fig. 30, p. 133), Dipterocarpeae, *Monotes*, Malvaceae (Fig. 34, p. 149), Sterculiaceae, Tiliaceae, Rutaceae, Ochnaceae, Burseraceae, Meliaceae, Olacineae, Octocnemaceae, Hippocrateaceae, Rhamneae, Sapindaceae, Melianthaceae, Connaraceae, Caesalpinieae, Mimoseae, Rosaceae, Saxifragaceae, Droseraceae (special forms of stellate hairs, see Fig. 71, p. 325), Hamamelideae, Rhizophoraceae, Myrtaceae, Melastomaceae (Fig. 79, p. 362), Lythrarieae, Samydaceae, Turneraceae, Begoniaceae, Umbelliferae, Araliaceae (Fig. 98, p. 429), Cornaceae, Caprifoliaceae, Rubiaceae, Lobeliaceae, Ericaceae (Fig. 110, p. 485), Ebenaceae, Styraceae, Loganiaceae (Fig. 124, p. 542), Hydrophyllaceae, Boragineae, Convolvulaceae (Fig. 129, p. 567), Solanaceae, Scrophularineae, Verbenaceae, Labiatae (Fig. 152, p. 638), Nyctagineae, Chenopodiaceae (Fig. 159, p. 659), Nepenthaceae, Monimiaceae, Elaeagnaceae, Santalaceae, Euphorbiaceae (Fig. 180, p. 748), Juglandeae, Cupuliferae.

The following **types of stellate and tufted hairs deserve special notice.** The spiny hairs (Fig. 2, *B, C*, p. 22) of the Dilleniaceae are reduced tufted hairs, consisting of a group of strongly silicified epidermal cells, which are developed as short hairs ; if we imagine the marginal cells of the group to be differentiated as rays, we obtain the stellate trichomes of the Dilleniaceae. Cushion-shaped structures, which are similar to the spiny hairs of the Dilleniaceae, although they are not silicified, occur also in the Cistineae (Fig. 21, p. 81) and Melastomaceae. The stellate hairs of the genus *Steriphoma* (Capparideae, Fig. 19, p. 75) resemble the peltate hairs of the Capparideae in being provided with a small upper scale, while some of the stellate hairs found in the Cistineae show the same apparent doubling of the ray-cells in the longitudinal direction (Fig. 21, p. 81), as is seen in the simple trichomes occurring in this Order. Stellate or tufted hairs with uniseriate rays have been observed in certain Magnoliaceae?, Anonaceae, Malvaceae (Fig. 34, p. 149), Sterculiaceae, Tiliaceae, Hippocrateaceae, Rhamneae, Lecythidaceae and Ericaceae (Fig. 110, p. 485), while in the stellate hairs of *Axyris* (Chenopodiaceae, Fig. 159, p. 659) the principal ray alone is uniseriate. The two-armed hairs of *Aldrovanda* (Fig. 71, p. 325), which show transverse division into two cells, may be regarded as a reduced form of the stellate hairs of certain of the Droseraceae, in which the ray-portion is composed of four or more thin-walled rays, expanded in one plane. The stellate hairs of the Loganiaceae-Buddleioideae are likewise specially characteristic, since the ray-portion consists of two (mostly two-rayed) cells, which also contribute to the formation of the stalk (Fig. 124, p. 542). Mention may lastly be made of: (*a*) the tufted hairs of *Saurauja* (Ternstroemiaceae, Fig. 30, p. 133) and certain Melastomaceae, which resemble small scales ; (*b*) the tufted hairs of *Santiria* (Burseraceae, Fig. 43, p. 191) and *Rhus* (Anacardiaceae), which may possibly have a glandular function ; and (*c*) the peculiar stellate hairs of some Araliaceae (Fig. 98, p. 429), which are provided with uniseriate rays having thin walls.

The simplest kinds of **candelabra- or abietiform hairs** are those which have a uniseriate main axis, interrupted at intervals by whorls of ray-cells. Such hairs are occasionally connected by means of transitional forms with the stellate and tufted hairs just discussed, hairs of the latter type not uncommonly appearing as reduced forms of the candelabra-hairs and then often occurring side by side with them in the same species. The candelabra-hairs of the second type present a different appearance, owing to the fact that the ray-cells follow upon one another in the longitudinal direction without interruption, there being no special cells of the main axis separating the rays from one another. These candelabra-hairs are often difficult to distinguish from the branched sympodial hairs discussed in § 31, p. 1120 ; and similarly, if the stalks of such candelabra-hairs are multiseriate, it is not easy to distinguish them from candelabra-hairs of the shaggy type, so that the latter may be considered together with the ordinary candelabra-hairs. Candelabra-hairs of the shaggy type may be derived from ordinary shaggy hairs (§ 33) by the development of

superficial cells of the latter in the form of hairs (this process occasionally taking place in tiers).

Candelabra-hairs of the first type have been observed in certain Lythrarieae, Ericaceae (Fig. 110, p. 485), Buddleioideae (Loganiaceae, Fig. 124, p. 542, the tiers here consisting of two (mostly two-rayed) cells, as in the case of the analogous peltate and stellate hairs, see above), Scrophularineae (Fig. 135, p. 580), Verbenaceae, Chenopodiaceae (Fig. 159, p. 659), and Platanaceae (Fig. 184, p. 780); candelabra-hairs of the second type occur in certain Capparideae (Fig. 19, p. 75), Melastomaceae (Fig. 79, p. 362), Umbelliferae (Fig. 95, p. 421), Solanaceae (Fig. 133, p. 577), and Acanthaceae; **candelabra-hairs of the shaggy type**, lastly, are found in certain Caesalpinieae, Mimoseae (Fig. 65, p. 295), Melastomaceae (Fig. 79, p. 362), Samydaceae, Labiatae (Fig. 152, p. 638), and Euphorbiaceae (Fig. 180, p. 748).

§ 33. Shaggy Hairs (i.e. clothing hairs of the shaggy type, villi). **Simple** (i.e. unbranched) **shaggy hairs** are widely distributed in many Orders. They vary in length and thickness, and consist of parenchymatous or prosenchymatous cells with thin or thick (sclerenchymatous) walls. The filiform shaggy hairs are frequently distinguished by the fact that the apices of the superficial cells are drawn out into papillae, which point towards the end of the shaggy hair; a more extensive development of the apices of the cells results in the production of trichomes, which are transitional to the candelabra-hairs of the shaggy type, already discussed at the end of § 32.

Simple shaggy hairs, which otherwise vary in shape, are found in the following Orders: Papaveraceae, Capparideae (Fig. 19, p. 75), Portulaceae (Fig. 26, p. 112), Ternstroemiaceae (Fig. 30, p. 133), Papilionaceae (Fig. 59, p. 268), Caesalpinieae, Mimoseae (Fig. 65, p. 295), Saxifragaceae, Crassulaceae, Droseraceae, Halorageae, Myrtaceae sens. str., Melastomaceae (Fig. 79, p. 362), Lythrarieae, Begoniaceae (Fig. 88, p. 401), Cacteae, Umbelliferae, Araliaceae (Fig. 98, p. 429), Compositae (Fig. 103, p. 458), Ericaceae (Fig. 110, p. 485), Convolvulaceae, Gesneraceae, Polygonaceae and Euphorbiaceae.

In the following cases the **shaggy hairs** are **specially differentiated**. Silicified wart-shaped shaggy hairs are found in *Gunnera*; in *Cranocarpus* (Papilionaceae) the tip of the shaggy hair has the form of an anchor, the flukes of the anchor being formed by pointed cells, each of which includes a crystal of oxalate of lime (Fig. 59, *G*, p. 268), which is pointed like the cell containing it; in certain Melastomaceae, which exhibit a great degree of diversity in the forms of the shaggy hairs, the latter occasionally show surface-development, so that they come to resemble the leaf of a Moss (Fig. 79, p. 362), while in certain *Begonias* they are two-armed or star-like (Fig. 88, p. 401); in the genus *Picris* (Compositae, Fig. 103, p. 458) the shaggy hair is crowned by a two-armed cell, while the forked shaggy hairs of *Leontodon*, which are well known to systematists, are produced by two or more of the terminal cells of the trichome being differentiated as hairs. The shaggy hairs of *Picris* are closely related to the emergences of *Humulus*, each of which bears a two-armed trichome. Reduced forms of shaggy hairs are found on the floral organs of the Compositae (Fig. 103, p. 458); they consist either of two basal cells and two longer cells, the latter lying parallel to one another and (in *Sphaeranthus*) embracing one another spirally, or merely of two cells, which are placed parallel to one another (as in the sensitive hairs of the Cynareae). The peculiar hollow structures, found in *Heterotrichum* (Melastomaceae), must also be included among the shaggy hairs; their wall is formed by a prosenchymatous epidermis and a layer of reduced palisade-cells. With the shaggy hairs of *Picris* and *Humulus* we may associate trichomes having a stalk of varying length and a stellate or tufted terminal portion; these structures have already been dealt with under stellate and tufted hairs in § 32. The 'candelabra-hairs of the shaggy type' have likewise been considered in the same section. Shaggy hairs, which are provided with glandular heads, will be discussed under

the heading of glandular shaggy hairs in the section dealing with the external glands (see § 34 under II, p. 1129).

Branched shaggy hairs have been observed in *Calandrinia* (Portulaceae; these are the 'pili plumosi,' mentioned by different authors) and in certain Melastomaceae (the hairs here being penicillate or branched in a dendroid manner and at the same time parenchymatous).

The shaggy hairs, as already stated in § 30, are partly epidermal structures and partly of the nature of emergences. To the latter category there belong, among other types of trichomes, the shaggy hairs of certain *Begonias* and Melastomaceae, which are stiffened by means of isolated sclerenchymatous fibres or by whole bundles of such fibres and (in the Melastomaceae) occasionally include a vascular bundle in their basal portion. In the Melastomaceae the bundle of sclerenchyma in these shaggy hairs is frequently connected with cells of the mesophyll, which are differentiated like fibres; in those shaggy hairs, which are placed obliquely to the surface of the organ, these fibres form an **anchoring foot**, consisting of a bundle of sclerenchymatous fibres, which spread out for some distance beneath the epidermis; on the other hand, when the shaggy hair is placed at right angles to the surface, the fibrous foot is branched after the manner of a root (Fig. 79, p. 362); the shaggy hairs of *Cirsium* (Compositae) show similar features. We may add that a similar sclerenchymatous foot has been observed also in the Mimoseae (Fig. 65, p. 295) and Euphorbiaceae (Fig. 180, p. 748) in connexion with trichomes of a more complicated type, such as candelabra-, peltate and stellate hairs. Certain species of *Croton* are quite particularly noteworthy in this respect; in these species the bases of the hairs are formed by a bundle of sclerenchymatous cells, which traverse the leaf in the vertical direction, while the bases of two trichomes, situated opposite one another on the upper and lower surface of the leaf, are fused to form a sclerenchymatous column, traversing the entire thickness of the leaf (Fig. 180, p. 748).

At this point we may also refer to the branched or unbranched structures resembling shaggy hairs found in the intercellular spaces of *Nelumbium* (Nymphaeaceae).

§ 34. HAIR-LIKE EXTERNAL GLANDS[1]. The demonstration of external glands and the investigation of their structure in herbarium-material often presents great difficulties. It is a familiar fact that glandular hairs are often functional only on the young organs of a plant, and in this case fall off in later stages or shrivel up, so that their structure becomes unrecognizable. As a consequence external glands are best sought after and examined on the young leaves, found on the branches of herbarium-material, or even on the young branches themselves (especially those of the floral region); but, whenever it is at all possible, living material should also be employed in determining the presence of external glands and in the elucidation of their structure and function.

In certain Orders (e.g. Sapindaceae, Oleaceae, &c.) hair-like external glands are of general or almost general distribution; in other Orders they are restricted to certain genera, while in others again glandular hairs are completely absent. It is worthy of note that the subsequent enumeration of Orders, in which external glands have not been observed, includes whole series of closely allied Orders, as well as many Orders, in which the secretory requirements of the plant are apparently sufficiently satisfied by internal secretory organs.

As a rule the hair-like external glands occur on all the organs of the plant, although in varying abundance; in other cases—and this holds good for species, as well as for genera and Orders—they are found only on certain parts of the plant. Thus in the Rubiaceae, for instance, glandular hairs are almost completely wanting on the surfaces of the leaves and on the branches, while

[1] For the hair-like internal glands (internal glandular hairs) found in *Pogostemon* (Labiatae), see under secretory cells in § 14 (p. 1096).

external glands, having a complicated structure and serving for the protection of the buds, occur on the stipules, and glands, excreting nectar and showing the same type of structure, are found in the flowers. It is necessary to take such features into account in an investigation of the hairy covering.

Another difficulty, with which one is confronted in employing the occurrence of external glands for systematic purposes, was already briefly referred to in § 29, and lies in the fact that the glandular hairs are not in all cases distinguished morphologically, and that the presence of secretion cannot always be determined in herbarium-material with as much certainty as is desirable. In addition to that the ordinary clothing hairs may exceptionally take on a secretory function in certain Orders (e.g. the uniseriate hairs of the Nymphaeaceae and Gentianeae, and the two-armed trichomes of the Sapotaceae [1]).

Hair-like external glands have not been observed in any form in the following Orders and genera respectively: Dilleniaceae, Calycanthaceae, Magnoliaceae, Trochodendraceae, Lactoridaceae, Anonaceae, Sarraceniaceae (with external glands, which are not of the nature of hairs, see § 38), Papaveraceae, Fumariaceae, Resedaceae, Violarieae (apart from glandular shaggy hairs on the margin of the leaf), Canellaceae, Polygaleae, Vochysiaceae (apart from nectaries, see § 36), Frankeniaceae (apart from chalk-glands, see § 37), Tamariscineae (apart from chalk-glands, see § 37), Hypericineae, Guttiferae, Ternstroemiaceae ? (apart from nectaries, see § 36), Humiriaceae (with the exception of glandular shaggy hairs on the margin of the leaf), Malpighiaceae (apart from nectaries, see § 36), *Koeberlinia*, Ochnaceae, Luxemburgiaceae (excepting glandular shaggy hairs found on the stipules and sepals of the Godoyeae), *Wallacea*, Chailletiaceae, Olacineae ? (see p. 1117), Octocnemaceae, Ilicineae, Cyrilleae, Celastrineae, Hippocrateaceae, Pentaphylacaceae, Corynocarpaceae, Stackhousieae, Rhamneae (apart from glandular shaggy hairs situated on or near the margin of the leaf and (see § 36) the nectaries), Didiereae, Melianthaceae, Staphyleaceae (apart from nectaries, see § 36), Coriarieae, Moringeae (apart from nectaries, see § 36), Crossosomataceae, Hamamelideae, *Ostrearia*, *Myrothamnus*, Bruniaceae, Rhizophoraceae (apart from glandular shaggy hairs on the stipules), Myrtaceae sens. str., Samydaceae (apart from nectaries, see § 36), Papayaceae, Cacteae (see § 36), Ficoideae, Umbelliferae ?, Araliaceae (almost always), Rubiaceae (apart from glandular shaggy hairs on the stipules, &c.), Calycereae, Campanulaceae, Lobeliaceae, Epacrideae, Diapensiaceae, Sapotaceae (two-armed clothing hairs occasionally glandular), *Brachynema*, Styraceae ? (see p. 1117), Salvadoraceae, Apocynaceae and Asclepiadeae (apart from glandular shaggy hairs at the base of the petiole and the glandular hairs of *Dischidia*), Loganioideae (Loganiaceae, apart from glandular shaggy hairs at the base of the petiole), *Desfontainea*, Gentianeae (apart from uniseriate glandular trichomes in the aquatic forms and glandular bodies, composed of numerous cells, in saprophytes), Cuscuteae (apart from glandular shaggy hairs on the flower), Columelliaceae, Nyctagineae ?, Amarantaceae ?, Phytolaccaceae, Batideae, Aristolochiaceae, Chloranthaceae, Myristicaceae ?, Monimiaceae, Laurineae, Gomortegaceae, Proteaceae ?, Thymelaeaceae, *Octolepis*, *Gonystylus*, Penaeaceae, *Geissoloma*, Elaeagnaceae, Loranthaceae, Santalaceae, *Myzodendron*, *Champereia*, *Grubbia*, Balanophoreae, Daphniphyllaceae, Buxaceae ?, Balanopseae, Thelygoneae, Casuarineae, Salicineae (apart from nectaries, see § 36), Lacistemaceae; but also in certain genera of numerous other Orders.

The hair-like external glands show numerous points of difference as regards their size, shape, and structure (number, arrangement, and structure of the cells, and localization of the secretion), and it is almost impossible to comprise these in a single system, applicable to all the various Orders. For, one and the same form of trichome occurring in two different Orders may be of different

[1] A combination of the glandular and clothing functions in simple hairs, as well as in trichomes of more complicated structure, has been observed in the Orders Portulaceae, Caesalpinieae, Melastomaceae (particularly frequent in the tribe Miconieae, in which combinations of glandular hairs with stellate, tufted, candelabra- or peltate hairs occur in almost all the genera), Loganiaceae, Solanaceae, Myoporineae, Nyctagineae (see Fig. 154, p. 646) and Platanaceae; in hairs of this type the glandular portion may be restricted to a single cell or may be differentiated as a multicellular glandular body, which, as it were, is independent of the rest of the hair. For details, see the anatomical descriptions of the Orders named.

phylogenetic importance in the two cases; thus the uniseriate glandular hairs of the Solanaceae, in which the head is unicellular or divided by a vertical wall, form the starting-point for external glands with a uniseriate stalk and a variously shaped head, divided by horizontal or both by horizontal and vertical walls, while the glandular hairs of a similar structure, found in the Scrophularineae, constitute a starting-point for external glands, the head of which is divided by vertical walls only, that is to say for quite another type of hair.

For the purpose of the practical determination of a plant, we may in the following paragraphs first (under I) summarize especially the small forms of glandular hairs, which have a simple structure, in contrast to other types of glandular hairs, which are mostly of large size and generally have a complicated structure (see under II); it must, however, be pointed out that the boundary-line between the two kinds of hairs is artificial and therefore not sharply marked. The small glandular hairs may then in the first place be classified in two further groups in accordance with the remarks made in § 29; the second of these groups (I b) includes those forms of glandular hairs, in which the head is divided solely by vertical walls, while the other (I a) comprises all the remaining forms.

I a. **Unicellular glandular hairs**, which for the most part have a tubular shape, have been observed in the following Orders: Ranunculaceae (Fig. 1, p. 16), Menispermaceae, Malvaceae, Tiliaceae, Zygophylleae (Fig. 38, p. 168), Geraniaceae, Rutaceae, Olacineae ? (Fig. 48, p. 204), Ampelidaceae, Anacardiaceae, Papilionaceae, Onagrarieae, Cornaceae (Fig. 99, p. 435), Compositae (laticiferous hairs, which stand in connexion with the laticiferous vessels), *Dischidia* (Asclepiadeae), Monotropeae, *Symplocos* ? (Styraceae), Podostemaceae, Piperaceae (in the form of large pearl-glands, Fig. 168, p. 689), Euphorbiaceae (secretory cells of *Croton*, which are differentiated like papillae, see § 14 and Fig. 180, p. 748).

The **multicellular glandular hairs**, to be discussed here, are very diverse. In the simplest case they consist merely of a row of cells, which is either filiform or broadened towards the upper end in a clavate manner. The appearance of longitudinal division-walls in most of the cells, or only in the terminal portion of the hair, results in the formation of complicated, filiform or club-shaped glandular hairs, which are occasionally curved or involuted in a peculiar manner. Other types of glandular hairs are differentiated into a stalk and a head. The stalk varies in length, and is unicellular, uniseriate or composed of a few rows of cells, while the head, which varies in size, is spherical or ellipsoidal, or otherwise shaped, and consists of one or many cells; in those cases, in which the head is multicellular, it may be divided by horizontal walls only, or both by horizontal and vertical walls or quite irregularly.

The multicellular glandular hairs in question have been observed in the following Orders and genera: Menispermaceae (uniseriate), Berberideae (rare), Nymphaeaceae (uniseriate, in part very short, Fig. 12, p. 49), Cruciferae (uniseriate, head uni- or bicellular, Fig. 15, p. 63), Capparideae (diverse types, head in part unicellular), Cistineae (uniseriate, glandular hairs in part very long and filiform, Fig. 21, p. 81), Bixineae (various types), Pittosporeae (uniseriate), Caryophylleae (uniseriate, head unicellular, Fig. 25, p. 108), Portulaceae (uniseriate, Fig. 26, p. 112), Ternstroemiaceae ?, Dipterocarpeae (unicellular peltate head, Fig. 31, p. 137; see I b), *Monotes* (uniseriate), Chlaenaceae (various types), Malvaceae (various types, incl. uniseriate glands with a unicellular head; see I b), Sterculiaceae (various types), Tiliaceae (as in the Sterculiaceae), Geraniaceae (uniseriate with a unicellular, rarely multicellular head, Fig. 39, p. 170), Rutaceae (various types, Fig. 41, p. 177), Simarubaceae (diverse types, Fig. 42, p. 183), Burseraceae (various types, Fig. 43, p. 191), Meliaceae (various types, Fig. 45, p. 197), Sapindaceae (various types; see I b), Hippocastanaceae (as in the Sapindaceae), Aceraceae (various types), Sabiaceae (head unicellular; see I b), Anacardiaceae (various types; see I b), *Juliania*[1] (head multi-

[1] According to F. E. Fritsch, Trans. Linn. Soc. London, vii, 1908.

cellular), Connaraceae (only on the floral organs), Papilionaceae (various types, heads in part unicellular, Fig. 59, p. 268; see I b), Caesalpinieae (diverse types, Fig. 63, p. 287), Mimoseae (various types, Fig. 65, p. 295; see I b), Rosaceae (various types), Saxifragaceae (various types, heads in part unicellular; see I b), Crassulaceae (diverse types), Combretaceae (various types; see I b), Lecythidaceae (groups of uniseriate glands ?), Melastomaceae (various types; see I b), Loaseae (uniseriate), Turneraceae (various types; see I b), Cucurbitaceae (head uni- or multicellular, its cells occasionally drawn out into lappets; see I b), Begoniaceae (various types, Fig. 88, p. 401, head in part hammer-shaped; multicellular pearl-glands), Umbelliferae (??; certainly very rare), Araliaceae (uniseriate), Cornaceae (various types), Caprifoliaceae (various types; see I b), Valerianeae (multicellular heads; see I b), Dipsaceae (as in the Valerianeae), Compositae (various types, commonly **biseriate vesicular glandular hairs**, Fig. 103, p. 458; see I b), Candolleaceae (heads of diverse types; see I b), Goodeniaceae (multicellular heads; see I b), Vacciniaceae (various types; in some cases **biseriate ligulate glandular hairs**, Fig. 108, p. 478), Ericaceae (various types, occasionally uniseriate, Fig. 110, p. 485; see I b), Monotropeae (various types, see I b), Lennoaceae (uniseriate glands with a unicellular head), Primulaceae (uniseriate glands with a unicellular head, Fig. 114, p. 502; see I b), Myrsineae (head unicellular; see I b), Ebenaceae (uni- or multicellular heads; see I b), *Plocosperma*, Polemoniaceae (heads unicellular or divided by means of horizontal walls into several tiers, which are themselves divided by vertical walls; see I b), Hydrophyllaceae (various types, in part with unicellular heads; see I b), Boragineae (heads unicellular and variously shaped, Fig. 126, p. 557), Convolvulaceae (various types, in part uniseriate, Fig. 129, p. 567; see I b), Nolaneae (heads of diverse types, also unicellular), Solanaceae (various types, heads in part unicellular, Fig. 133, p. 577; see I b), *Retzia* (diverse types), Scrophularineae (unicellular heads; see I b), Orobanchaceae (as in the Scrophularineae), Lentibularieae (as in the Scrophularineae), Gesneraceae (as in the Scrophularineae), Acanthaceae (as in the Scrophularineae), Myoporineae (as in the Scrophularineae), Verbenaceae (as in the Scrophularineae), Labiatae (rarely unicellular heads, which are of large size and have a cuticle, which is strongly elevated in a vesicular manner, otherwise as in the Scrophularineae), Plantagineae (various types; see I b), Nyctagineae (uniseriate, in part branched, with unicellular heads, Fig. 154, p. 646; hairs really glandular ?), Illecebraceae (uniseriate with unicellular heads), Amarantaceae (as in the Illecebraceae, glandular ?), Chenopodiaceae (uniseriate, Fig. 159, p. 659), Polygonaceae (unicellular heads; see I b), Piperaceae (unicellular heads; hydathodes, Fig. 168, p. 689) Myristicaceae (see p. 699), Hernandiaceae (*Illigera* with a transversely septate, bicellular head, Fig. 172, p. 708), Proteaceae (Fig. 173, p. 713), Euphorbiaceae (various types, heads in part unicellular; see I b), Ulmaceae (various types), Cannabineae (Fig. 181, p. 769; see I b), Moraceae (various types, in part uniseriate; see I b), Urticeae (see I b), Platanaceae (unicellular heads), Leitnerieae, Myricaceae (various types, in part uniseriate; see I b), Cupuliferae (diverse types, in part uniseriate, Fig. 187, p. 793; see I b), Empetraceae (various types, heads in part unicellular, Fig. 188, p. 800).

It remains to mention the following **special forms of the multicellular glands** (apart from those already indicated in the preceding review by the use of heavy type): (*a*) the peltate glandular hairs of certain Papilionaceae (Fig. 59, p. 268), Mimoseae and Droseraceae (Fig. 71, p. 325), which have a shield composed of two layers of cells; (*b*) the spherical glands of certain Papilionaceae (especially Phaseoleae), in which abundant secretion is deposited between the cells of the head (which are in loose connexion with one another), and in a subcuticular position (Fig. 59, p. 268); (*c*) the peltate or spherical glands of certain Papilionaceae (Fig. 59), Caesalpinieae (Fig. 63, p. 287) and Lythrarieae (Fig. 80, p. 370), which enclose an intercellular secretory space; (*d*) the branched external glands of certain species of *Santiria* (Burseraceae, Fig. 43, p. 191), *Rhus* (Anacardiaceae) and *Mimosa* (Mimoseae), and of *Conocephalus* and *Sparattosyce* (Moraceae); (*e*) the penicillate mucilage-hairs of certain species of *Candollea* (Candolleaceae), which show special peculiarities in certain stages of their development, and are provided with two or more uniseriate rays, which are bi- or multicellular; (*f*) lastly, the external glands of certain Melastomaceae, which have two or four, or even more heads situated on a common stalk, and the paired glands, found in species of *Acer* (Aceraceae).

in which the unicellular stalks are fused lengthwise with one another. Finally, brief mention may be made of the occasional combination of glandular hairs in groups (Compositae, Ficoideae [1], Moraceae, see also § 36 under nectaries), and the outgrowth of cells of the stalks of the glandular hairs in a papillose or hair-like manner (in certain Melastomaceae).

I b. The **glandular hairs, the heads of which are divided solely by means of vertical walls**[2], may be divided into those which have peltate heads, and those which have spherical heads. The former for the most part have short stalks, while the latter generally have longer stalks, the stalks often being of considerable length. The number and mode of arrangement of the cells forming the head (which is of variable size) varies, occasionally even in the trichomes of one and the same species. In most cases there is only a slight accumulation of secretion beneath the cuticle. **Vesicular integumental glands of the peltate type**, in which the cuticle is raised like a bladder owing to the formation of abundant secretion, have been recorded only in a few Orders (Mimoseae, Combretaceae, Fig. 76, p. 346, Melastomaceae, Turneraceae ?, Fig. 83, p. 382, Compositae ?, *Anthotroche*, Bignoniaceae, Fig. 141, p. 603, Verbenaceae, Labiatae, Fig. 152, p. 638, Euphorbiaceae, Cannabineae, Fig. 181, p. 769, and Myricaceae). Special forms of these glands are constituted by the mucilage-hairs of certain species of *Candollea*, in which the cells of the head are rod-shaped, and the well-known kamala-glands of *Mallotus* (Euphorbiaceae) with a head, composed of club-shaped cells. **Other special forms of the glandular hairs in question** are as follows. Large peltate glands, which are differentiated after the manner of the intra-mural glands, are found in *Rhododendron* and *Ledum* (Ericaceae, Fig. 110, p. 485), while special types of glands, the heads of which are divided solely by a single vertical wall, occur in some of the Buddleioideae (Loganiaceae, Fig. 124, p. 542). Characteristic peltate glands (Fig. 135, p. 586) are widely distributed in the Rhinanthaceae ; these glands consist of a uni- or multicellular basal portion, a middle cell and a group of 2–4 lid-cells, covering the middle cell. Peltate glands of quite a similar type are found also in *Monophyllaea* (Gesneraceae), the glands here excreting chalk and having two lid-cells. Other particularly noteworthy forms are : (*a*) the glandular hairs of certain Lentibularieae (Fig. 139, p. 596), which are provided with a stellate or two-armed terminal portion, composed of four and two cells respectively, these glands resembling the stellate hairs of certain Droseraceae, already mentioned in § 32 ; (*b*) the curious forked glands of *Primulina* (Gesneraceae) ; (*c*) the glandular hairs of certain Gesneraceae, which are provided with a stellate head with 3–4 rays ; (*d*) the mucilage-glands of many Pedalineae, in which the outer walls of the glandular head, which consists of four or more cells, become mucilaginous (Fig. 143, p. 612) ; (*e*) the peculiar peltate glands of the Myoporineae (Fig. 149, p. 626), in which the stalk is excentric ; (*f*) the shortly stalked chalk-glands of the Selagineae (Fig. 150, p. 629), the heads of which consist of two cells and mostly have two knobs ; (*g*) the external glands of certain Gesneraceae and of the Thunbergieae (Acanthaceae, Fig. 144, p. 615), which are provided with a hammer-shaped or biscuit-shaped head, divided by a transverse wall ; and (*h*) the peculiar external glands of *Littorella* (Plantagineae, Fig. 153, p. 643).

Glandular hairs with a spherical or peltate head, divided exclusively by one or more vertical walls, and consisting of two or many cells, are found in the following Orders and genera : Bixineae, Dipterocarpeae (Fig. 31, p. 137 ; see I a), *Ancistrocladus* (Fig. 32, p. 143), Malvaceae (scarcely typical ; see I a), Burseraceae, Sapindaceae

[1] In *Glischrothamnus*, according to Pilger, in Engler, Bot. Jahrb., xl, 1908, p. 397.

[2] The term 'vertical wall' is not always to be interpreted in the exact geometrical sense. When the heads of the glandular hairs consist of numerous cells and are strongly arched outwards, the division-walls namely converge towards the stalk, the cells of the head in such cases being generally elongated in a palisade-like manner.

(see I a), Hippocastanaceae (see I a), Sabiaceae (see I a), Anacardiaceae (see I a), Papilionaceae (very rare; see I a), Mimoseae (Fig. 65, p. 295; see I a), Saxifragaceae (see I a), Droseraceae (*Byblis*), Halorageae (Fig. 72, p. 337), Combretaceae (Fig. 76, p. 346; see I a), Melastomaceae (see I a), Turneraceae (Fig. 83, p. 382; see I a), Cucurbitaceae (see I a), Caprifoliaceae (Fig. 100, p. 441; see I a), Valerianeae (see I a), Compositae ? (see I a), Dipsaceae (see I a), Candolleaceae (see I a), Goodeniaceae (see I a), Ericaceae (Fig. 110, p. 485; see I a), Monotropeae (see I a), Primulaceae (see I a), Myrsineae (Fig. 116, p. 510; see I a), Ebenaceae (see I a), Oleaceae (Fig. 110, p. 523), Loganiaceae (Fig. 124, p. 542), Polemoniaceae (see I a), Hydrophyllaceae (see I a), Convolvulaceae (Fig. 129, p. 567; see I a), Solanaceae (Fig. 133, p. 577; see I a), Scrophularineae (Fig. 135, p. 586; see I a), Orobanchaceae (see I a), Lentibularieae (Fig. 136, p. 592; see I a), Gesneraceae (Fig. 140, p. 599; see I a), Bignoniaceae (Fig. 141, p. 603), Pedalineae (Fig. 143, p. 612), Acanthaceae (Fig. 144, p. 615; see I a), Myoporineae (Fig. 149, p. 626; see I a), Selagineae (Fig. 150, p. 629), Verbenaceae (Fig. 151, p. 632; see I a), Labiatae (Fig. 152, p. 638; see I a), Plantagineae (Fig. 155, p. 643; see I a), Polygonaceae (see I a), Nepenthaceae (Fig. 165, p. 670), Cytinaceae, Euphorbiaceae (see I a), Cannabineae (Fig. 181, p. 760; see I a), Moraceae (see I a), Urticeae (see I a), Juglandeae, Myricaceae (see I a), Juglandeae, Myricaceae (see I a), Cupuliferae (Fig. 187, p. 793; see I a).

II. **Hair-like external glands**[1], **which are generally of large size and in most cases have a complicated structure.** We may first mention the following forms. Multicellular lageniform or urceolate glands (Fig. 34, p. 149) occur in certain Malvaceae. Pearl-glands, which are composed of many (sometimes very many) cells, are found in certain Sterculiaceae, Ampelidaceae (Fig. 52, p. 223), Caesalpinieae, Begoniaceae, Moraceae, and Urticeae; some of these glands have an epidermis of small cells, which includes a stoma situated on the side opposite to the stalk. Spherical glands with a palisade-epidermis and a pair of guard-cells, situated on the side opposite to the short stalk, occur in *Leea* (Ampelidaceae, Fig. 52, p. 223). Small, almost sessile, cucullate glands are found at the base of a depression (which is provided with a narrow aperture) in the surface of the plant in *Laguncularia* (Fig. 76, p. 346) and *Conocarpus* (Combretaceae). Other forms requiring mention are the lageniform external glands of *Dictamnus* (Rutaceae, Fig. 41, p. 177), the basal portion of which includes a secretory cavity, and the cylindrical emergences of *Eucalyptus* (Myrtaceae, Fig. 77, p. 353), which likewise contain a secretory cavity. The external glands of *Dictamnus* are closely related on the one hand to the conical glandular shaggy hairs of *Cuphea lanceolata* (Lythrarieae, Fig. 80, p. 370), which are composed of numerous cells and contain a group of secretory cells in their basal portion, and on the other hand to the bulbous hairs of certain Papilionaceae, Caesalpinieae (Fig. 59, p. 268, and Fig. 63, *A*, p. 287) and Turneraceae (Fig. 83, p. 382), in which there is no secretory cavity in the swollen base of the gland. The retort-shaped glands of certain Caesalpinieae (Fig. 63, *D*, p. 287), lastly, constitute somewhat reduced forms of bulbous hairs, the basal portion of which is sunk into the tissue of the organ bearing them; with them we may class the retort-shaped hairs of *Bellucia* (Melastomaceae), which are merely uniseriate and have a basal portion, divided by numerous septa. The remaining external glands, to be included here, are **glandular shaggy hairs**, having a multiseriate stalk of varying length and a head, which is either (rarely, in Menispermaceae, Fig. 7, p. 41, Papilionaceae, Convolvulaceae, Cuscuteae) unicellular or irregularly multicellular or (in very many cases, see Fig. 101, p. 446) consists of a central core of cells, which are elongated in the direction of the length of the stalk and are enveloped by one or more layers of secretory palisade-cells. The stalk (and sometimes also the core in those glands, the heads of which are provided with a palisade-epithelium) often contains a vascular bundle or the termination of a vascular bundle. Glandular shaggy hairs, showing the type of structure just described, are occasionally (e.g. in the Rosaceae and Euphorbiaceae) connected by transitions with glandular spots, having an identical structure (see § 36).

[1] For the external glands found in insectivorous plants, see § 38, p. 1133.

Glandular shaggy hairs have been observed in the following Orders and genera: Menispermaceae (Fig. 7, p. 41), Cruciferae (Fig. 15, p. 63), Capparideae, Tremandreae, Elatineae, Tiliaceae, Lineae, Geraniaceae, Simarubaceae (Fig. 42, p. 183), Luxemburgiaceae (Godoyeae, on the stipules and sepals), Rhamneae (for the most part only on the margin of the leaf), Sapindaceae, Aceraceae (occasionally separating into two uniseriate hair-like filaments at the apex, see p. 893), Papilionaceae, Mimoseae, Rosaceae, Saxifragaceae (Fig. 68, p. 316), *Penthorum*, Crassulaceae, Droseraceae (digestive glands, showing a uniform type of structure, Fig. 71, p. 325), Halorageae (Fig. 72, p. 337), Rhizophoraceae (generally on the stipules only), Melastomaceae, Lythrarieae, Turneraceae (Fig. 83, p. 382), Passifloraceae (Fig. 84, p. 385), Begoniaceae, Datisceae, Araliaceae, Rubiaceae (only on the stipules and floral organs, Fig. 101, p. 446), Compositae, Candolleaceae, Vacciniaceae, Ericaceae, Monotropeae, Plumbagineae, Apocynaceae (on the petioles, &c.), Asclepiadeae (for the most part as in the Apocynaceae), Loganiaceae (as in the Asclepiadeae), Gentianeae (rare, in the axils or on the surface of the leaves), Convolvulaceae, Cuscuteae (in the flower), Solanaceae (Fig. 133, p. 577), Polygonaceae, Nepenthaceae (pitcher- and nectarial glands), Euphorbiaceae, Thelygoneae, Ceratophylleae (apices of the leaves). For details as to the structure of the glandular shaggy hairs, see the individual Orders.

The varied **nature of the secretion**, produced by the hair-like external glands, has already been repeatedly referred to (see also § 29), and it is only necessary to add that excretion of carbonate of lime or of some other salt has been observed in certain Papilionaceae, Convolvulaceae, Scrophularineae, Gesneraceae, Bignoniaceae and Selagineae. In some cases the secretion of resin is so considerable that the leaves become covered with a perfect layer of varnish [1].

External glands, which are sunk in the surface of the leaf, occasionally give rise to transparent dots.

§ 35. GLANDULAR LEAF-TEETH [2] are found in species belonging to a large number of Orders. According to the type of structure they show they may be grouped in three categories. In the first case the leaf-teeth bear the same kinds of glandular hairs as occur on the surface of the leaf; in the second case they have a secretory epidermis, which is differentiated like palisade, or they are completely transformed into glandular shaggy hairs, the epidermis of which shows the same differentiation; and in the third case they include the termination of a vascular bundle, which is associated with an epithema (often containing mucilage), the epidermis above the latter containing one or more water-pores. Leaf-teeth of the first and second types secrete resin, while those of the third type secrete mucilage or water (the latter in some cases contains chalk, which becomes deposited on the surface of the plant, e.g. in the Violarieae and Saxifragaceae). The process of secretion frequently takes place only in the young leaf. The glandular leaf-teeth in some cases no doubt function also as extrafloral nectaries.

The structure of the glandular leaf-teeth has been examined in the following Orders: Ranunculaceae, Trochodendraceae, Cruciferae, Violarieae, Caryophylleae, Ternstroemiaceae, Tiliaceae, Humiriaceae, Geraniaceae, Celastrineae, Rhamneae, Aceraceae, Staphyleaceae, Ampelidaceae, Papilionaceae, Rosaceae, Saxifragaceae, Hamamelideae, Halorageae, Onagrarieae, Cucurbitaceae, Caprifoliaceae, Dipsaceae, Compositae, Campanulaceae, Vacciniaceae, Primulaceae, Gentianeae, Polemoniaceae, Scrophularineae, Verbenaceae, Labiatae, Ulmaceae, Cannabineae, Moraceae, Juglandeae, Cupuliferae, Salicineae. For details, see under the individual Orders.

§ 36. LARGE GLANDULAR MECHANISMS (NECTARIES) [3]. At this point

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[1] Volkens, Lack. Bl., Sitz.-Ber. deutsch. bot. Gesellsch. 1890, p. 120.

[2] See Reinke, in Pringsheim Jahrb., x, 1876, p. 119; and Virchow, Blattzähne, Archiv d. Pharm., 1896.

[3] See especially Poulsen, Trik. og Nektar., Vidensk. Meddel. naturh. For. Kjøbenhavn, 1875, abstr. in Just, 1875, p. 1213; Bonnier, Nect., Ann. sc. nat., sér. 6, t. viii, 1878; [Davis, Nectar-

I propose to give a collective account of the large glandular mechanisms, generally described as nectarial glands or nectaries. The glands in question vary very much in structure. They do not always form a secretion, which contains sugar or is of the nature of honey, for the secretion is sometimes mucilaginous or like wax, while in other cases (in the hydathodes) it is no doubt merely water ; so that the term 'nectary' is not always suitable. Owing to their large size these glands are visible even to the naked eye, and have therefore been recorded in many Orders by systematists. In some Orders they are of such general occurrence that they constitute a diagnostic character aiding in the recognition of a member of the Order, while in other Orders they are found either in all (e.g. *Qualea*, Vochysiaceae) or only in certain species of a genus. Only those nectaries, which appear on the vegetative organs, will be considered here; very commonly, however, nectaries occur on the inflorescence and on the sepals, either side by side with those on the vegetative organs or to the exclusion of the latter. The position, in which they occur on the leaf, varies. They may be present to the number of one or more on either side of the base of the petiole in the form of disc-shaped or wart-like glands ; in other cases they are shifted up on to the petiole, where they constitute wart-like appendages, or are developed in the form of depressed callosities on its upper side, while not uncommonly they are situated at the limit of lamina and petiole, appearing as discoid, wart-shaped or pit-like structures. In other cases again they are found on the lower side of the lamina, although sometimes restricted to the basal portion ; the nectaries on the lamina are developed as pit-like callosities on the midrib or apex of the leaf, as disc-shaped structures on the leaf-margin, and as shallow pit-like or disc-shaped glands, or as mere spots on the lower surface of the leaf, where they occur in varying numbers and occasionally show a definite arrangement with reference to the veins. Nectaries are rarely found also on the upper surface of the leaf. They have, however, also been observed on the stipules, and in some cases they are metamorphosed stipules or stipels (Sterculiaceae, Caprifoliaceae, Leguminosae, Combretaceae); in the species of *Capparis*, belonging to the section *Cynophalla*, DC., moreover, they are transformed foliage-shoots. The structure of the nectaries is very diverse, and on the basis of these differences in structure the majority of the nectaries may be classified in two series, which are connected with one another by transitional forms. The nectaries of the first series are composed of groups of small glandular hairs, which are found either (*a*) on the surface of the organ, or (*b*) in shallow depressions in the surface, or (*c*) clothing deep pits of diverse structure in the surface of the organ, these pits often being provided with a narrow ostiole, or (*d*) lining the inner wall of hollow glandular bodies, which have an ovoid form (Olacineae). The structure of the glandular hairs forming these nectaries is, as a general rule, identical with that of the external glands, which are found as isolated trichomes on the vegetative organs of the species in question, although the secretory portion is usually more strongly developed. To this series belong the nectaries found in certain Menispermaceae, Malvaceae, Sterculiaceae, Olacineae, Papilionaceae (Fig. 59, p. 268), Oleaceae, Convolvulaceae and Polygonaceae, as well as the glandular zones on the stems of certain Sileneae (Fig. 25, p. 108). The simpler forms of the nectaries of the first series are related to the groups of glandular hairs, mentioned in § 34 (p. 1128), and the latter can to some extent be regarded as initial stages in the development of

glands on leaves, Bot. Gazette, 1883, p. 339]; Delpino, Funz. mirmecof., Mem. Acc. Bologna, 1886, p. 215, and 1888, p. 601 ; Morini, Nett. estranuz., Mem. Acc. Bologna, 1886, p. 325, and 6 tab., here also the older literature; Haupt, Sekretionsmechanik d. extranupt. Nekt., Flora, 1902, p. 1, also Diss., Leipzig; Schwendt, Extraflorale Nektarien, Beih. z. Bot. Centralbl., xxii, Abt. 1, 1907, p. 245 et seq. and tab. ix.

such nectaries. The forms of nectaries, comprised in the second series, are more widely distributed than those of the first series. The former in the first place show all transitions between bodies, which project in the form of a head, wart, or disc, and may occasionally even be stalked, and structures formed solely by a group of superficial cells on the organ bearing the gland. In the two extreme types of the nectaries belonging to this series, as well as in their intermediate forms, the glandular tissue may consist throughout of small polyhedral cells with thin walls, or the epidermis of the gland may be differentiated as a palisade-epithelium ; when the latter is strongly elongated, each of its prismatic cells is frequently divided by a transverse wall. Pit-like nectaries, which occasionally have a number of subsidiary excavations and open to the exterior by means of a wide or narrow orifice, are very rare, but have been observed, for example, in *Marcgravia* (Ternstroemiaceae), *Coprosma* (Rubiaceae), *Fagraea* (Loganiaceae), and in the Nepenthaceae (Fig. 164, p. 678); the pits in these nectaries are clothed by one or several layers of secretory palisade-cells.

In the following synopsis of the Orders, in which '**extrafloral nectaries**' occur, details as to their shape and distribution are added only in those cases in which the structure of the glands has not yet been investigated, so that, as a general rule, they have not been considered in the earlier part of this book : Menispermaceae, Capparideae (axillary nectaries in species of *Capparis* belonging to the section *Cynophalla*), Bixineae (two large nectaries at the base of the leaf in *Scolopia* and *Idesia*, also glandular leaf-teeth), Vochysiaceae (impressed nectaries on either side of the base of the petiole in *Qualea*), Caryophylleae, Ternstroemiaceae (Marcgravieae), Dipterocarpeae, Malvaceae, Sterculiaceae, Tiliaceae (glandular leaf-teeth in *Grewia* and *Triumfetta*), Humiriaceae, Malpighiaceae (Fig. 36, p. 164), Geraniaceae (glandular warts on the petiole in *Impatiens*), Rutaceae (in *Boronia*, also discoid or wart-shaped nectaries on the lower side of the leaf in species of *Zanthoxylon*), Simarubaceae (in *Ailanthus* and *Cadellia*, also wart-like nectaries on both surfaces of the leaf in species of *Samadera*), Olacineae, Rhamneae, Staphyleaceae (two glands on the base of the leaf in *Huertea*), Anacardiaceae (wart-like nectaries on the upper part of the petiole or in place of the stipels in *Holigarna*), Moringeae (nectaries, which are occasionally stalked, at the base of the pinnules and on the petiole in *Moringa*), Papilionaceae (Fig. 59. p. 268), Caesalpinieae, Mimoseae, Rosaceae, Combretaceae, Lecythidaceae, Lythrarieae (thick bodies, provided with an open pore and situated at the end of the midrib of the leaf in *Lafoensia*, acarodomatia ?), Samydaceae (nectaries at the apex of the petiole or on the margin of the leaf in *Banara*), Turneraceae, Passifloraceae, Cucurbitaceae (nectaries of diverse shape, often discoid, situated either on the entire lower side of the leaf or confined to the base of the leaf in species of *Abobra, Adenopus, Alsomitra, Bryonia, Cephalandra, Cucurbita, Feuillea, Lagenaria, Luffa, Momordica, Sphaerosicyos, Trianosperma, Trichosanthes*), Cacteae (see Delpino), Caprifoliaceae, Rubiaceae, Compositae (at the base of the foliage-leaves in the floral region of *Helianthus*), Vacciniaceae, Ebenaceae (nectaries on the lower side of the leaf in species of *Diospyros* and *Royena*), Oleaceae, Loganiaceae, Convolvulaceae, Scrophularineae, Bignoniaceae (Fig. 141, p. 603), Verbenaceae, Polygonaceae, Nepenthaceae, Euphorbiaceae (Fig. 180, p. 748), Moraceae, Salicineae.

For groups of water-pores (hydathodes) appearing as small pits, warts or spots on the surface of the leaf, see § 5, p. 1086.

Before leaving this subject we may point out that the glandular spots and pits, which have been included among the nectaries, must not be confused with so-called **acarodomatia**[1]. The latter are commonly differentiated as small pits or pockets, and have been recorded in the following Orders : Magnoliaceae, Anonaceae, Menispermaceae, Violarieae, Bixineae, Ternstroemiaceae (incl. Marcgravieae), Dipterocarpeae, Sterculiaceae, Tiliaceae, Meliaceae, Ilicineae, Rhamneae, Sapindaceae, Aceraceae, Anacardiaceae, Rosaceae, Saxifragaceae (Ribesieae), Hamamelideae, Combretaceae, Myrtaceae, Melastomaceae, Lythrarieae, Cornaceae, Caprifoliaceae, Rubiaceae, Compositae, Sapotaceae, Oleaceae, Apocynaceae, Asclepiadeae, Logania-

[1] See especially Penzig e Chiaberra, Piante acarofile, Malpighia, 1902, p. 413 et seq.

ceae, Boragineae, Solanaceae, Bignoniaceae, Verbenaceae, Piperaceae, Laurineae, Euphorbiaceae, Urticaceae (incl. Ulmaceae), Platanaceae, Juglandeae, Cupuliferae.

§ 37. Chalk- and Salt-Glands of the Frankeniaceae, Tamariscineae and Plumbagineae. These glands are distinguished by the fact that they are not differentiated as hairs. Their structure is simple and identical in the Frankeniaceae (Fig. 24, p. 106) and Tamariscineae, while in the Plumbagineae (Fig. 113, p. 497) it is of a more complicated type. In this Order one also finds mucilage-glands, which show a similar structure, apart from the fact that they consist of still more numerous cells (Fig. 113). Mucilage-glands, which are differentiated as hairs, have also been observed in the Plumbagineae, while glandular shaggy hairs occur on the inflorescence, and in respect of their structure both kinds of trichomes can be derived from the above-mentioned mucilage-glands, which are not of the nature of hairs.

For glandular hairs, excreting chalk or other salts, see the end of § 34 (p. 1130); regarding leaf-teeth, which excrete chalk, see § 35 (p. 1130).

§ 38. Special Forms of External Glands occurring in Insectivorous Plants. The glands of the Sarraceniaceae are not hair-like, although in other respects they show diverse structure (see p. 53 et seq. and Fig. 13); glands of a similar kind are found also in *Cephalotus* (see p. 310 and Fig. 69). The Nepenthaceae have nectarial glands, which are not of the nature of hairs, but take the form of small pits, the wall of which is lined by three layers of secretory cells (see § 36); in this Order one also finds nectarial and digestive glands, which are differentiated as hairs and have 2-3 layers of secretory cells (see p. 677 et seq. and Fig. 164). The glands of the Droseraceae (Fig. 71, p. 325) are always developed as hairs and in all the genera (with the sole exception of the genus *Byblis*, which, according to Lang, must be transferred from the Droseraceae to the Lentibularieae) are distinguished by having two layers of secretory cells and a suberized middle layer.

§ 39. Cork-Warts on the leaves. In certain species the lower sides of the leaves bear numerous brown dots, which are often styled glands in anatomical descriptions, and may therefore be discussed at this point. These dots, however, as shown by a microscopical examination, are not glandular, but represent local formations of cork—so-called cork-warts. Mention may also be made here of the constant occurrence of corky tissue at the apices of the leaves in the Bruniaceae.

Cork-warts have been observed in the following Orders: Berberideae, Guttiferae, Ternstroemiaceae, Ilicineae (Fig. 50, p. 210), Celastrineae, Hippocrateaceae, Chrysobalaneae, Saxifragaceae, Hamamelideae, Rhizophoraceae, Myrtaceae sens. str., Melastomaceae, Lythrarieae, Araliaceae (only on the petiole), Apocynaceae, Loganiaceae, Gesneraceae, Piperaceae, Laurineae ?, Loranthaceae, Euphorbiaceae.

V. Normal Structure of the Axis.

§ 40. Medullary Tissue. Gris [1] was the first to show that the presence or absence of starch in the pith, as in the case of the endosperm of the seed, is a character of systematic importance. He distinguishes (i) active medullary cells, i. e. cells storing starch and generally having rather thick walls, (ii) empty medullary cells, i. e. dead cells filled with air and for the most part having

[1] Gris, Moëlle, Nouv. Arch. du Mus. d'hist. nat., t. vi, 1870, p. 201 and pl. xii-xx, and also Ann. sc. nat., sér. 5, t. xiv, 1872, p. 34 and pl. 4-7; Kassner, Mark einiger Holzpfl., Diss., Breslau, 1884, 38 pp., 2 Tab.; Magoscy-Dietz, Diaphragma in dem Mark d. dikotyl. Holzgew., Math. u. naturwiss. Ber. aus Ungarn, xvii, 1901, p. 181 et seq. (this paper deals with nodal, and not with internodal diaphragms); [Foxworthy, Discoid pith in woody plants, Proc. Indiana Acad. Sc. 1903 (1904), pp. 191-4]

relatively thin walls, and (iii) cells containing crystalline elements or some kind of secretion. The occurrence of an **empty or active pith**, consisting of empty cells only, or of active cells only, as the case may be (secretory cells or cells containing crystals being present or absent), or the occurrence of a **heterogeneous pith**, formed both by empty and active cells, is characteristic of taxonomic groups of varying magnitude. The varied distribution of the empty and active cells in a heterogeneous pith may, moreover, also be employed as a systematic character. The active cells either form a network between the empty cells or are confined to the periphery of the pith, the central portion of which in the latter case is occupied by empty cells. The fact that the active cells do not contain starch all the year round, so that they cannot always be recognized in herbarium-material with as much certainty as is desirable, constitutes an obstacle to the extensive practical use of all these features.

The occurrence of spicular cells and of special secretory elements in the pith has already been dealt with in the previous sections (see § 9 and § 14 et seq.). It remains to mention the following features: (*a*) the pith of certain species of *Myzodendron*, which consists throughout of prosenchymatous cells; (*b*) the groups of **sclerenchymatous fibres**, situated at the outer margin of the pith and in direct contact with the primary xylem-groups of the vascular bundles, in certain Menispermaceae, Malvaceae, Corynocarpaceae, Araliaceae, Polygonaceae, Loranthaceae, species of *Myzodendron*, Proteaceae, Platanaceae, Salicineae, &c., and the ring of sclerenchymatous fibres, occupying the same position in the young branches of species of *Piper*; (*c*) lastly, the occurrence of isolated sclerenchymatous fibres or of groups of such fibres in the interior of the pith in *Lophira* and in certain Meliaceae, Geraniaceae, Rutaceae, Lythrarieae, Araliaceae (*Aralidium*), Plumbagineae, Asclepiadeae, Euphorbiaceae, and Salicineae.

The occurrence of groups of **stone-cells** in the pith is generally only of importance for specific diagnosis. Horizontal diaphragms, composed of stone-cells and forming transverse septa in the pith, possess greater systematic value; they have been observed in many Magnoliaceae, Anonaceae (Fig. 5, p. 35), and Ternstroemiaceae, as well as in *Brachynema* and certain Convolvulaceae.

Other features of systematic value are the complete or partial disappearance of the pith—the fistular character of the stem in older internodes (Umbelliferae !), and especially the septation of the pith without sclerosis (Fig. 185, p. 784), which goes hand in hand with a partial disappearance of the pith. The last feature has been observed in the following genera, of which it is generally (but not always, e. g. *Jasminum*) characteristic: *Wormia* (Dilleniaceae), *Diplotaxis* (Cruciferae), *Fouquiera* (Tamariscineae), *Prinsepia* (Chrysobalaneae), *Aucuba* (Cornaceae, only in herbarium-material !), *Senecio* (Compositae), *Halesia* (Styraceae), *Jasminum* (Oleaceae), *Paulownia* (Scrophularineae), *Pedalium* (Pedalineae), *Phytolacca decandra* (Phytolaccaceae)[1], *Daphniphyllum* (Daphniphyllaceae), *Juglans* and *Pterocarya* (Juglandeae).

§ 41. Appearance of the Transverse Section of the Stem in Herbaceous Plants. The great diversity, shown by the appearance of the transverse section of the stem in herbaceous plants, is mainly due to the varied extent of development or to the complete or partial absence of mechanical tissue accompanying the vascular bundles on their inner and outer side, and to the diverse structure of the secondary wood, formed within the vascular bundles, and of the interfascicular tissue (presence or absence of wood-fibres, vessels and medullary rays)[2]. With the help of these features we are able to

[1] According to Mirbel and Holm, see Holm, in Merck's Report, xvi, 1907.
[2] See Schwendener, Mech. Prinzip, Leipzig, 1874, p. 142 et seq. and Tab. xiv.

distinguish a number of different types of transverse section, but it would be out of place to enter into a detailed description of them at this point, since it has been shown (see Ranunculaceae, Cruciferae, &c.) that they are only of very limited systematic value (in most cases they can be employed only for specific diagnosis); and, apart from that, the occurrence of intermediate forms often renders distinction between the principal types a difficult matter.

In certain Ranunculaceae (Fig. 1, p. 16), Berberideae [1], and Fumariaceae, and according to Schwendener also in certain Plumbagineae and Compositae, the line of demarcation between the phloem and xylem of the vascular bundles, as seen in a transverse section of the stem, has the shape of an arc, the concave side of which (and not the convex side, as is generally the case) is directed outwards [2].

§ 42. SYSTEMATIC IMPORTANCE OF THE STRUCTURE OF THE WOOD in the woody Dicotyledons [3]. The structure of the wood affords a whole series of anatomical characters, which are generally distinctive of genera or even of tribes or Orders. The most important of these characters are as follows: the kinds of perforations found in the vessels; the structure of the walls of the vessels in contact with parenchyma of the medullary rays or with wood-parenchyma; the nature of the pits (simple or distinctly bordered) on the walls of the wood-prosenchyma (wood-fibres), which forms the ground-mass

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[1] In *Caulophyllum thalictroides*, Michx., according to a recent observation of my own.

[2] For the structure of subterranean stems, see Costantin, Tiges aér. et sout. des Dicotyl., Ann. sc. nat., sér. 6, t. xvi, 1883, p. 5 et seq., and Noelle, Vergl. anat. Untersuch. der Auslaufer, Diss., Freiburg i. Br., 1892, 72 pp.

[3] Sanio, in Bot. Zeit., 1863, pp. 85 and 357 et seq.; Rossmann, Bau des Holzes, Frankfurt a. M., 1865, 100 pp.; De Bary, Vergl. Anat., 1877, p. 493 et seq.; Möller, Beitr. z. vergl. Anat. des Holzes, Denkschr. Wiener Akad., xxxvi, 1876, pp. 297–426 and Tab. i–vi; Solereder, Systemat. Wert der Holzstruktur, München, 1885, 264 pp.; Vesque, in Bull. Soc. bot. de France, 1889, p. lxv; Houlbert, Bois sec. dans les Apétales, Ann. sc. nat., sér. 7, t. xvii, 1893, also Thèse, Paris, 1893; Petersen, Diagnostisk Vedanatomi, Kjøbenhavn, 1901, 93 pp.; Stone, Anatomical characters in the identificat. of wood, Nature, lxv, 1901–2, pp. 379, 380; Wiesner, Rohstoffe, 2. Aufl., Bd. ii, 1903, p. 1 et seq.; Moll and Janssonius, Mikrographie des Holzes der auf Java vorkommenden Baumarten, Heft 1, Leiden, 1906, 368 pp. (Dilleniaceae to Dipterocarpeae, in the sequence of Durand's Index), especially Allgem. Teil, pp. 40–62; Perrot et Gérard, Anat. du tissu ligneux dans ses rapports avec la diagnose des bois, Bull. Soc. bot. de France, Mém. 6, 1907, 43 pp., 6 pl.

As regards the nomenclature of the elements of the wood, I may point out that practical considerations lead me in the first place to distinguish only three types of elements (apart from the parenchyma of the medullary rays), the distinctions being based on purely morphological characters, since this seems most suitable for the purposes of systematic-anatomical investigations; the three kinds of elements are: (*a*) the wood-vessels (cell-fusions, serving for the conduction of water); (*b*) the wood-parenchyma (elements, which conduct and store up carbohydrates); and (*c*) the wood-prosenchyma or the wood-fibres (elements, which always have a more or less pronounced mechanical function, but at the same time occasionally also participate in the functions of the vessels or of the wood-parenchyma). In this terminology the following elementary organs of Sanio's nomenclature are comprised under the term 'wood-prosenchyma': (*a*) the simple- or bordered-pitted libriform and the septate libriform, which according to Sanio constitute a system in the wood, comparable to the bast-fibres; (*b*) the intermediate fibres, which are shorter than the libriform fibres, store up starch, and function as a substitute for the wood-parenchyma; for this reason they are included in Sanio's parenchymatous system along with the wood-parenchyma; lastly (*c*) the tracheides (included in Sanio's tracheal system together with the vessels), which, when they form the ground-mass of the wood, can only be distinguished with difficulty from libriform bearing bordered pits, while in other cases such a distinction is scarcely possible. The use of the term 'tracheides' may be restricted to such xylem-elements as bear bordered pits and are of the nature of fibres; they occur side by side with simple-pitted wood-prosenchyma (libriform) and show distinct transitions to the vessels in the detailed structure of their walls and in the occasional presence of perforations at the ends of the cells. The exact nature of the wood-prosenchyma within the prescribed limits must naturally be taken into consideration in a detailed description. See also Caspary, in Pringsheim Jahrb., iv, 1864, p. 121, and Schriften d. physikal.-ökonom. Gesellsch. Königsberg, xxviii, 1887, p. 27 et seq.; Möller, loc. cit., p. 301; and Petersen, Trakeide, Oversigt Danske Vidensk. Selsk. Forh., 1901, n. 1, pp. 95–108 (with a French résumé).

of the wood; the abundant or scanty development of wood-parenchyma; the breadth and structure of the medullary rays. Those structural features, which vary with the amount of moisture in the soil and air, and the degree of transpiration on the part of the plant (e.g. chiefly the relative abundance of the vessels and the width of their lumina), are for the most part of minor systematic value (cf. the Introduction). This statement applies also to the presence or absence of those xylem-elements, which we have distinguished as tracheides, intermediate fibres and septate fibrous cells (cf. foot-note 3 on p. 1135), and which are developed side by side with the wood-prosenchyma (the latter forming the ground-mass of the wood); the relatively small systematic value of these elements corresponds with their function as forms physiologically intermediate between the wood-prosenchyma and the vessels, or between the wood-prosenchyma and the wood-parenchyma, as the case may be.

In practice, the determination of a piece of wood is based, primarily, on the coarser features, and especially on those which are recognizable in a transverse section with the help of a lens (e.g. the breadth of the medullary rays; the size of the lumina, the mode of arrangement and the relative abundance of the vessels; and the formation of annual rings, which depends on the features last named, and is found also in the wood of tropical plants), as well as on certain physical properties (such as hardness, colour, and occurrence of heart- and splint-wood)[1]. These features can only be employed to a very limited extent for systematic-anatomical purposes, since some of them can be detected only in pieces of wood, which have attained a certain degree of thickness; at the present time, moreover, a systematic investigation of the wood of foreign plants can only be undertaken on branches of herbarium-material, owing to the difficulty in obtaining correctly determined material of exotic stems. For the same reason we will only briefly refer to the numerical methods, employed by various authors for the purpose of specific diagnosis; these methods consist in the determination of the number of vessels found in a certain surface-area (one square millimetre) of the transverse section, or of the number of medullary rays (which are approximately parallel to one another in older stems) situated along a line, which is a definite number of millimetres in length, and is perpendicular to the direction of the rays; in certain species these numbers are constants.

§ 43. WOOD-VESSELS. The absence of xylem-vessels in woody Dicotyledons is a very rare phenomenon, which has been recorded only in the genera *Drimys* and *Zygogynum* (Magnoliaceae) and the genera *Tetracentron* and *Trochodendron* (Trochodendraceae); it is possible that the absence of vessels in these genera may be explained on phylogenetic grounds, the structure of their wood being altogether like that of the Coniferae. The absence of vessels is of more frequent occurrence in certain succulents, water-plants, and parasites, in which it is to be regarded as an indication of reduction. This is the case in the following forms: the Nymphaeaceae; *Aldrovanda* (Droseraceae); the Cacteae, in which the secondary wood is provided with peculiar annular and spiral tracheides; certain of the Monotropeae; the Cuscuteae; the Podostemaceae and Ceratophylleae[2]; and lastly, the thorns of *Balanites* (Simarubaceae), when they are destitute of leaves.

The anatomical features, which require to be taken into special consideration in examining the vessels of the secondary wood (briefly styled 'vessels' in the diagnoses of the Orders) with a view to their employment for systematic purposes, are as follows. In the first place it is necessary to notice the mode of **arrangement and the width of the vessels.** The latter are either isolated or lie in radial or tangential groups comprising two or more

[1] See R. Hartig, Unterscheidungsmerkmale der wichtigeren, in Deutschland wachsenden Hölzer, München (1st edit., 1878, &c.); Nordlinger, Querschnitte i–xi, 1852–88 (including also transverse sections of the wood of exotic plants); and other authors.

[2] See Caspary, in Monatsber. Berliner Akad., 1862, p. 448 et seq.

vessels. The width of the lumina of the vessels varies greatly, being very considerable, especially in lianes, but small in species having an ericoid habit, and altogether in plants inhabiting dry localities. For taxonomic purposes it is important to know the 'medium diameter' and the 'maximum diameter.' The **abundance of the vessels** is likewise a very variable feature. The diverse appearance of the annual rings [1], especially in the woody plants of our zones, is related to the structural differences just mentioned. All these features are epharmonic, and therefore in most cases merely constitute specific characters, and it is only when all the species of a certain group live under identical conditions that theyare characteristic of more extensive taxonomic groups,—in some cases even of Orders. The systematic employment of these features is rendered difficult by the fact that they are occasionally developed in a characteristic manner only in the later growth of the wood, so that it is impossible to obtain an adequate knowledge of them from an investigation of the branches of herbarium-material. For the purpose of distinguishing between the wood from the trunk of different trees they have been in practical use for a long time (cf. § 42).

Other characters, to be noticed in the course of an examination of the transverse section of a branch, are the round or angular **outline of the vessels and the thickness of their walls.** The plugging of the vessels of the heartwood with resinous or gummy substances is a widely distributed phenomenon, but is occasionally found also in the wood of perfectly young branches, especially in such plants as have secretory organs in the ground tissue: regarding plugs of silica or carbonate of lime, see §§ 26 and 27 (p. 1111). Details are at present wanting as to the systematic value of tyloses [2], but the latter appear to occur only in certain species.

A further character to be kept in view is the type of perforation ('Gefässdurchbrechung')[3], found on the division-walls between the segments of the vessels; these **perforations** are either simple or scalariform. Simple perforations are found both on horizontal and on more or less strongly inclined division-walls, their outline being circular on the horizontal walls, and varying from circular to elliptical (occasionally even elongated-elliptical) on the inclined walls. Scalariform perforations are in most cases met with only on strongly inclined division-walls; the bars, which vary in number (few or very many bars) and thickness, are generally placed transversely to the longitudinal axis of the vessel, while the outline of the perforation is for the most part elliptical (the ellipse occasionally being drawn out to a very considerable extent). Special forms of scalariform perforations (which, we may notice at once, are not of any great systematic interest and generally occur in the same piece of wood side by side with one of the two chief types of perforations) are as follows: (*a*) perforations, in which the two halves of the bars (i.e. those parts of the bars, which belong to the adjoining end-walls of two contiguous segments of the vessel) are shifted parallel to one another or intersect one another (in certain Compositae); (*b*) perforations, in which the bars are arranged obliquely or parallel to the longitudinal axis of the perforation; (*c*) malformed scalariform perforations, in which only a small number of bars or only imperfectly differentiated bars are present; (*d*) perforations, in which the bars form an elegant network as, the result of anastomosis (in certain Compositae, Rosaceae, Nyctagineae); (*e*) the peculiar perforations of certain species of *Epacris* (Fig. 112, p. 493);

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[1] Ursprung, Anat. u. Jahresringbild. trop. Holzarten, Diss., Basel, 1900, 82 pp.; Moll and Janssonius, Mikrographie d. Holzes, Heft 1, Leiden, 1906.

[2] Cf. De Bary, Vergl. Anat., 1877, p. 179.

[3] See Tangl, Perforationen an Pflanzengef., Sitz.-Ber. Wiener Akad., lxiii, Abt. 1, 1871, 12 pp. and Tab., and lxvii, Abt. 1, 1873, 14 pp. and Tab.; Solereder, Über den syst. u. phylogenet. Wert der Gefässdurchbrech., Bot. Centralbl., 1888, i, pp. 315-19.

(*f*) perforations, in which the division-walls of the vessels are traversed by rather a large number of circular or elliptical holes of varying size ('foraminate perforations') (in *Myrothamnus* and certain Dilleniaceae, Ericaceae and Vacciniaceae, Fig. 109, p. 479); (*g*) lastly, the combinations of simple and scalariform perforations, which have been observed in certain *Begonias* (Fig. 89, p. 405) and *Quillaja* (Rosaceae). As a rule the mode of origin of the perforated areas on the division-walls (either from simple pits or from bordered pits of large size) is of no great systematic value, since their development often varies in one and the same longitudinal section [1].

In a given species the perforations of the vessels are either exclusively simple or exclusively scalariform, or both simple and scalariform. In the latter case the two kinds of perforations either occur side by side with one another in the vessels of the secondary wood (occasionally we even find a simple perforation at one end, and a scalariform perforation at the other end of the same segment), or the scalariform perforations are confined to the primary wood and its immediate neighbourhood. When simple perforations are found in the same plant side by side with those of the scalariform type, the outline of the former is more commonly elliptical than circular, and in some cases even elongated-elliptical.

The **presence or absence of scalariform perforations** has mostly proved to be of value for the diagnosis of extensive taxonomic groups (Orders, tribes, genera). Certain groups have only simple or only scalariform perforations in the vessels, while others show a tendency to form scalariform perforations; this tendency betrays itself in the fact that different genera or different species of the same genus may in one case have exclusively scalariform perforations, and in another case both simple and scalariform perforations, although the perforations are never exclusively simple (scalariform perforations occurring at least in or near the primary wood, even if they are wanting in the secondary wood). Simple perforations are more widely distributed than those of the scalariform type. The constant occurrence of scalariform perforations in all the members of an Order is a rare phenomenon, found only in a very limited number of Orders, which are all of small size.

It remains to mention the striking fact that the occurrence of scalariform perforations in the vessels often goes hand in hand with small lumina in the vessels and the presence of bordered pits on the wood-prosenchyma.

Exclusively simple perforations are found in the same species in: Ranunculaceae pro parte, Calycanthaceae, Lactoridaceae, Anonaceae, Menispermaceae, Berberideae pro parte, Papaveraceae, Cruciferae, Capparideae, Resedaceae, Cistineae, Violarieae pro parte, Bixineae pro parte, Pittosporeae, Tremandreae pro parte, Polygaleae, Vochysiaceae, Frankeniaceae, Caryophylleae, Portulaceae, Tamariscineae pro parte, Elatineae, Hypericineae, Guttiferae, Ternstroemiaceae pro parte, Dipterocarpeae, *Ancistrocladus*, Chlaenaceae, Malvaceae, Triplochitonaceae, Sterculiaceae pro parte, Tiliaceae pro parte, Lineae pro parte, Malpighiaceae, Zygophylleae, Geraniaceae, Rutaceae pro parte, Simarubaceae pro parte, *Koeberlinia*, *Balanites*, Burseraceae, Meliaceae, Chailletiaceae pro parte, Olacineae pro parte, Celastrineae pro parte, Hippocrateaceae pro parte, Corynocarpaceae, Stackhousieae, Rhamneae pro parte, Ampelidaceae pro parte, Sapindaceae (almost always), Didiereae, Hippocastanaceae pro parte, Aceraceae, Melianthaceae, Anacardiaceae pro parte, Coriarieae, Moringeae, Connaraceae, Papilionaceae, Caesalpinieae, Mimoseae, Chrysobalaneae, Crassulaceae, Droseraceae pro parte, Halorageae, Combretaceae, Myrtaceae sens. str. pro parte, Lecythidaceae, Melastomaceae, Lythrarieae, Onagrarieae pro parte, Samydaceae pro parte, Loaseae, Passifloraceae pro parte, Papayaceae, Cucurbitaceae, Datisceae, Cacteae, Ficoideae, Umbelliferae pro parte, Araliaceae pro parte, *Carlemannia* (Caprifoliaceae), Rubiaceae pro parte, Calycereae, Compositae pro parte, Candolleaceae, Goodeniaceae, Lobeliaceae, Ericaceae pro parte ?, Epacrideae

[1] See Solereder, Holzstruktur, 1885, p. 15.

pro parte ?, Lennoaceae, Plumbagineae, Primulaceae, Myrsineae pro parte, Sapotaceae pro parte, Ebenaceae, Styraceae pro parte, Oleaceae pro parte, Salvadoraceae, Apocynaceae, Asclepiadeae, Loganiaceae pro parte, Gentianeae pro parte, Polemoniaceae pro parte, Hydrophyllaceae, Boragineae, Convolvulaceae, Solanaceae, *Retzia*, Scrophularineae, Orobanchaceae, Gesneraceae, Bignoniaceae, Pedalineae, Acanthaceae, Myoporineae, Selagineae, Verbenaceae pro parte, Labiatae pro parte, Plantagineae, Nyctagineae (division-walls very rarely perforated in a reticulate manner), Illecebraceae, Amarantaceae, Chenopodiaceae pro parte (almost always), Basellaceae, Phytolaccaceae, Batideae, Polygonaceae, Nepenthaceae, Cytinaceae, Aristolochiaceae, Piperaceae pro parte, Laurineae pro parte, Hernandiaceae pro parte, Proteaceae, Thymelaeaceae, *Gonystylus*, Penaeaceae, Elaeagnaceae, Loranthaceae, Santalaceae, *Myzodendron*, *Champereia*, Balanophoreae ?, Euphorbiaceae pro parte, Buxaceae pro parte, Ulmaceae pro parte, Cannabineae, Moraceae, Urticeae, Leitnerieae, Juglandeae pro parte, Salicineae.

Exclusively scalariform perforations are found in the same species in: Ranunculaceae pro parte, Dilleniaceae pro parte, Magnoliaceae pro parte, Trochodendraceae pro parte, Violarieae pro parte, Canellaceae, Bixineae pro parte, Ternstroemiaceae pro parte, Rhaptopetalaceae, Humiriaceae, Olacineae pro parte, *Scytopetalum*, Ilicineae, Cyrilleae, Celastrineae pro parte, Staphyleaceae pro parte, Saxifragaceae pro parte, *Penthorum*, Droseraceae pro parte, Hamamelideae, *Myrothamnus*, *Ostrearia*, Bruniaceae, Rhizophoraceae pro parte (Rhizophoreae), Myrtaceae pro parte, Samydaceae pro parte, Passifloraceae pro parte, Cornaceae pro parte, Caprifoliaceae pro parte, Dipsaceae pro parte ?, Vacciniaceae pro parte, Ericaceae pro parte, Epacrideae pro parte, Myrsineae pro parte, *Brachynema*, Styraceae pro parte, *Desfontainea*, Columelliaceae, Piperaceae pro parte, Chloranthaceae, Monimiaceae pro parte, Laurineae pro parte, Gomortegaceae, *Geissoloma*, *Grubbia*, Euphorbiaceae pro parte, Daphniphyllaceae, Buxaceae pro parte, Balanopseae, Myricaceae pro parte, Cupuliferae pro parte, Lacistemaceae, Empetraceae pro parte.

Simple and scalariform perforations are found side by side in the same species in: Dilleniaceae pro parte, Magnoliaceae pro parte, Trochodendraceae pro parte, Berberideae pro parte, Violarieae pro parte, Bixineae pro parte, Tremandreae pro parte, Tamariscineae pro parte, Ternstroemiaceae pro parte, Sterculiaceae pro parte, Tiliaceae pro parte, Lineae pro parte, Rutaceae pro parte, Ochnaceae, Simarubaceae pro parte, Chailletiaceae pro parte, Olacineae pro parte, Celastrineae pro parte, Hippocrateaceae pro parte, Rhamneae pro parte, Ampelidaceae pro parte, Sapindaceae pro parte, Hippocastanaceae pro parte, Staphyleaceae pro parte, Sabiaceae, Anacardiaceae pro parte, Rosaceae (excl. Chrysobalaneae), Crossosomataceae, Saxifragaceae pro parte, Rhizophoraceae pro parte (Legnotideae), Onagraneae pro parte, Samydaceae pro parte, Turneraceae, Passifloraceae pro parte, Begoniaceae, Umbelliferae pro parte, Araliaceae pro parte, Cornaceae pro parte, Caprifoliaceae pro parte, Rubiaceae pro parte, Valerianeae, Dipsaceae pro parte, Compositae pro parte, Campanulaceae, Vacciniaceae pro parte, Ericaceae pro parte, Epacrideae pro parte, Diapensiaceae, Myrsineae pro parte, Sapotaceae pro parte, Oleaceae pro parte, Loganiaceae pro parte, Gentianeae pro parte, Polemoniaceae pro parte, Verbenaceae pro parte, Labiatae pro parte, Chenopodiaceae pro parte, Piperaceae pro parte, Myristicaceae, Monimiaceae pro parte, Laurineae pro parte, Hernandiaceae pro parte, Euphorbiaceae pro parte, Ulmaceae pro parte, Platanaceae, Juglandeae pro parte, Myricaceae pro parte, Casuarineae, Cupuliferae pro parte, Empetraceae pro parte.

As regards the **structure of the walls of the vessels** the following features are chiefly to be taken into consideration: the occurrence of spiral thickening on the walls of the pitted vessels of the secondary wood; the size and nature (outline of the border and of the aperture of the pit) of the bordered pits (occasionally scalariform bordered pits), found on the walls of contact between two vessels; the occurrence of a 'sieve-like' structure (first demonstrated by Bengt Jönsson [1]) on the pit-membranes of the bordered pits of the vessels; lastly, the varying structure of the walls of the vessels in contact with parenchyma of the medullary rays or with wood-parenchyma. These walls are

[1] Ber. deutsch. bot. Gesellsch., 1892, p. 494, and Tab. xxvii; see also Heiden, in Bot. Centralbl., 1893, iv, p. 3.

occupied (*a*) either by one-sided bordered pits, one or more of which correspond to large one-sided simple pits on the adjoining parenchyma-wall, or (*b*) by one-sided simple pits of varying size, which correspond to pits of equal dimensions on the wall of the adjoining parenchyma-cell; in the latter case transitional forms to distinct one-sided bordered pits frequently occur side by side with the simple ones. The systematic value of these features varies and requires to be tested in each individual case; the most valuable characters are afforded by the structure of the walls of the vessels in contact with parenchyma, which is occasionally constant throughout all the members of an Order (Burseraceae, Hamamelideae).

Spiral thickening of the walls of the vessels is generally only a specific character, and has been observed in the following Orders: Ranunculaceae, Calycanthaceae, Magnoliaceae, Trochodendraceae, Berberideae, Papaveraceae, Cruciferae, Capparideae, Bixineae, Pittosporeae (universally ?), Tremandreae, Polygaleae, Portulaceae, Ternstroemiaceae, Malvaceae, Sterculiaceae, Tiliaceae, Lineae, Malpighiaceae, Geraniaceae, Rutaceae, Meliaceae, Olacineae, Ilicineae, Celastrineae, Rhamneae, Sapindaceae, Hippocastanaceae, Aceraceae, Melianthaceae, Staphyleaceae, Anacardiaceae, Papilionaceae, Caesalpinieae, Rosaceae, Droseraceae, Hamamelideae (only on the ends of the segments of the vessels), Samydaceae, Ficoideae, Araliaceae, Cornaceae, Caprifoliaceae, Rubiaceae, Compositae, Vacciniaceae, Ericaceae, Epacrideae, Myrsineae, Oleaceae, Apocynaceae, Loganiaceae, Boragineae, Solanaceae, Scrophularineae, Bignoniaceae, Myoporineae, Selagineae, Verbenaceae, Labiatae, Illecebraceae, Chenopodiaceae, Phytolaccaceae, Polygonaceae, Aristolochiaceae, Monimiaceae, Laurineae, Proteaceae, Thymelaeaceae, Loranthaceae, Santalaceae, Buxaceae, Ulmaceae, Moraceae, Juglandeae, Casuarineae, Cupuliferae. Species, in which the walls of the vessels show spiral thickening, generally have spirally thickened tracheides as well. For the occurrence of special spirally thickened vessels or cells in the wood, see § 47 (p. 1145).

Scalariform bordered pits have been observed on the vessels of the secondary wood in certain Magnoliaceae, Violarieae, Ilicineae, Ampelidaceae, Bruniaceae, Rhizophoraceae, Begoniaceae, Apocynaceae, Piperaceae, Monimiaceae, Euphorbiaceae, Cupuliferae and in *Myzodendron*. The simple pitting of the walls of the vessels in the Papayaceae and Crassulaceae is due to their being embedded in unlignified tissue (see § 47, p. 1144).

Sieve-like structure of the pit-membranes in the bordered pits of the vessels has been recorded in the following Orders: Vochysiaceae, Guttiferae, Rhamneae, Hippocastanaceae, Papilionaceae, Caesalpinieae, Mimoseae, Amygdaleae, Combretaceae, Myrtaceae, Melastomaceae, Onagrarieae, Araliaceae, Compositae, Asclepiadeae, Oleaceae, Scrophularineae, Cupuliferae.

The occurrence of **simple and occasionally large pits on the walls of the vessels in contact with parenchyma** (sometimes side by side with bordered pits) has been recorded in the following Orders and genera respectively: Calycanthaceae, Magnoliaceae, Trochodendraceae pro parte, Violarieae, Bixineae pro parte, Tremandreae, Vochysiaceae pro parte, Tamariscineae pro parte, Hypericineae pro parte, Guttiferae pro parte, Ternstroemiaceae pro parte, Dipterocarpeae, Chlaenaceae, Malvaceae pro parte, Sterculiaceae pro parte, Tiliaceae pro parte, Lineae pro parte, Humiriaceae pro parte, Malpighiaceae pro parte, Geraniaceae, Rutaceae pro parte, Simarubaceae pro parte, Burseraceae, Olacineae pro parte, Rhamneae pro parte, Ampelidaceae, Hippocastanaceae, Staphyleaceae pro parte, Sabiaceae, Anacardiaceae, Moringeae, Connaraceae, Papilionaceae pro parte (rare), Rosaceae pro parte, Saxifragaceae pro parte, Hamamelideae, *Ostrearia*, Rhizophoraceae pro parte, Myrtaceae pro parte, Melastomaceae pro parte, Lythrarieae pro parte, Onagrarieae, Passifloraceae pro parte, Datisceae, Umbelliferae pro parte, Araliaceae, Cornaceae pro parte, Vacciniaceae pro parte, Myrsineae pro parte, Sapotaceae, *Brachynema*, Styraceae pro parte, Apocynaceae pro parte, Loganiaceae pro parte, Convolvulaceae, Solanaceae pro parte, Gesneraceae pro parte, Bignoniaceae pro parte, Acanthaceae pro parte, Verbenaceae pro parte, Labiatae pro parte, Phytolaccaceae pro parte, Piperaceae, Myristicaceae, Monimiaceae, Laurineae, Hernandiaceae, Gomortegaceae, *Geissoloma*, Santalaceae pro parte, *Grubbia*, Euphorbiaceae pro parte, Balanopseae, Moraceae pro parte, Urticeae, Leitnerieae, Juglandeae, Cupuliferae pro parte, Salicineae.

Bordered pits alone have been observed **on the walls of contact between vessels and parenchyma** in the following Orders and genera respectively: Trochodendraceae pro parte, Anonaceae, Menispermaceae, Capparideae, Canellaceae, Bixineae pro parte, Pittosporeae, Polygaleae, Vochysiaceae pro parte, Tamariscineae pro parte, Elatineae, Hypericineae pro parte, Guttiferae pro parte, Ternstroemiaceae pro parte, *Ancistrocladus*, Malvaceae pro parte, Triplochitonaceae, Sterculiaceae pro parte, Tiliaceae pro parte, Lineae pro parte, Humiriaceae pro parte, Malpighiaceae pro parte, Zygophylleae, Rutaceae pro parte (in most cases), Simarubaceae pro parte (almost always), *Koeberlinia*, *Balanites*, Ochnaceae, Meliaceae, Olacineae pro parte, Ilicineae, Cyrilleae ?, Celastrineae, Hippocrateaceae, Rhamneae pro parte, Sapindaceae, Aceraceae, Melianthaceae, Staphyleaceae pro parte, Papilionaceae pro parte (in most cases), Caesalpinieae, Mimoseae, Rosaceae pro parte, Crossosomataceae, Saxifragaceae pro parte, *Penthorum*, Droseraceae, *Myrothamnus*, Bruniaceae, Halorageae, Rhizophoraceae pro parte, Combretaceae, Myrtaceae pro parte, Melastomaceae pro parte, Lythrarieae pro parte, Samydaceae, Loaseae, Turneraceae, Passifloraceae pro parte, Umbelliferae pro parte, Cornaceae pro parte, Rubiaceae, Calycereae, Compositae, Goodeniaceae, Campanulaceae, Lobeliaceae, Vacciniaceae pro parte, Ericaceae, Epacrideae, Myrsineae pro parte, Ebenaceae, Styraceae pro parte, Oleaceae, Salvadoraceae, Apocynaceae pro parte, Asclepiadeae, Loganiaceae pro parte, *Desfontainea*, Gentianeae, Hydrophyllaceae, Solanaceae pro parte, *Retzia*, Scrophularineae, Columelliaceae, Gesneraceae pro parte, Bignoniaceae pro parte, Pedalineae, Acanthaceae pro parte, Myoporineae, Selagineae, Verbenaceae pro parte, Labiatae pro parte, Phytolaccaceae pro parte, Batideae, Polygonaceae, Chloranthaceae, Proteaceae, Thymelaeaceae, Penaeaceae, Elaeagnaceae, Santalaceae pro parte, *Champereia*, Euphorbiaceae pro parte, Daphniphyllaceae, Buxaceae, Ulmaceae, Moraceae pro parte, Myricaceae, Casuarineae, Cupuliferae pro parte, Lacistemaceae ?.

§ 44. WOOD-PROSENCHYMA. The most valuable systematic feature, afforded by the structure of the wood-prosenchyma, has proved to be the **nature of the pitting of the prosenchymatous ground-mass**[1] of the wood. The presence of distinct simple pits (i.e. without a border) or of distinct bordered pits (although the borders are sometimes small) on the wood-prosenchyma is often characteristic of entire Orders, tribes, genera or generic sections; in utilizing these features it is necessary to neglect the occurrence of small numbers of fibrous cells, provided with bordered pits (i.e. 'tracheides' which are transitional to the vessels), side by side with the wood-prosenchyma bearing simple pits, or of simple-pitted fibrous cells side by side with the bordered-pitted wood-prosenchyma. A more detailed classification of the wood-prosenchyma (cf. § 42, p. 1135, footnote 3) is not of much value in systematic-anatomical researches, as far as can be gathered from the experience hitherto obtained, among other reasons because a classification of this kind is partly based on physiological characters (viz. the cell-contents), so that it is impossible to apply it with the requisite precision, when using herbarium-material. Apart from those already mentioned, a few other structural features of the wood-prosenchyma deserve to be taken into consideration; the most important of these are the following: the varying size of the lumina and the diverse thickness of the walls; the occurrence of thin transverse walls in the wood-prosenchyma (septate wood-prosenchyma), a feature connected with the storage of starch in the lumina of the cells; the presence of starch in fibrous cells, which are not septate; the occurrence of a so-called gelatinous layer, viz. a cartilaginous thickening-layer of the cell-wall, consisting of hemicellulose and occasionally disappearing in the course of the metabolism of the plant; the detailed structure and abundance of the pits; the length of the cells and their mode of arrangement in a transverse section; the appearance of the cells in transverse section (outline and size, the latter occasionally varying

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[1] See also Gregory, Pores of the librif. tissue, Bull. Torrey Bot. Club, New York, 1887; abstr. in Bot. Centralbl., 1887, iii, p. 72.

in one and the same section, owing to the fact that the fibrous cells are cut through at different points in the course of their length), &c.

Although the distinction between wood-prosenchyma bearing bordered pits and that bearing simple pits is so simple in itself, the maintenance of this distinction, which is very important for systematic purposes, becomes very difficult, when the borders of the pits are very small; for, simple slit-shaped pits occasionally appear to be provided with a small border, when seen in surface-view. In such a case the appearance of the pit in transverse section can alone decide whether the pit is really bordered or not.

The **prosenchymatous ground-mass of the wood bears simple pits** in the following Orders and genera respectively: Ranunculaceae, Anonaceae, Berberideae pro parte, Papaveraceae, Cruciferae, Capparideae, Resedaceae, Cistineae pro parte, Violarieae, Bixineae pro parte, Pittosporeae, Tremandreae pro parte, Vochysiaceae (excl. Trigoniaceae), Frankeniaceae, Caryophylleae, Portulaceae, Tamariscineae pro parte, Hypericineae pro parte, Guttiferae pro parte, Ternstroemiaceae pro parte, Dipterocarpeae pro parte, Malvaceae, Triplochitonaceae, Sterculiaceae pro parte, Tiliaceae, Rhaptopetalaceae, Lineae pro parte, Malpighiaceae, Geraniaceae, Rutaceae, Simarubaceae pro parte (almost always), Ochnaceae pro parte, Burseraceae, Meliaceae, Corynocarpaceae, Rhamneae, Ampelidaceae, Sapindaceae, Didiereae, Hippocastanaceae, Aceraceae, Melianthaceae, Staphyleaceae pro parte, Sabiaceae pro parte, Anacardiaceae, Coriarieae, Moringeae, Connaraceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae pro parte (rare), Saxifragaceae pro parte, Crassulaceae, Halorageae, Rhizophoraceae pro parte (tribe Rhizophoreae), Combretaceae pro parte (in most cases), Lecythidaceae, Melastomaceae pro parte, Lythrarieae, Onagrarieae, Samydaceae, Loaseae pro parte, Turneraceae pro parte, Passifloraceae pro parte, Cucurbitaceae, Begoniaceae, Datisceae, Cacteae, Ficoideae, Umbelliferae, Araliaceae, Cornaceae pro parte, Caprifoliaceae pro parte, Rubiaceae pro parte, Valerianeae, Dipsaceae pro parte, Calycereae, Compositae, Lobeliaceae, Diapensiaceae pro parte, Plumbagineae, Myrsineae, Sapotaceae, Oleaceae pro parte, Salvadoraceae, Apocynaceae pro parte, Asclepiadeae pro parte, Loganiaceae pro parte, Gentianeae pro parte, Polemoniaceae, Boragineae pro parte, Solanaceae pro parte, ***Retzia***, Scrophularineae, Orobanchaceae, Gesneraceae, Bignoniaceae, Pedalineae, Acanthaceae, Myoporineae, ***Zombiana***, Selagineae pro parte, Verbenaceae, Labiatae, Plantagineae, Nyctagineae, Illecebraceae pro parte (rare), Amarantaceae, Chenopodiaceae, Phytolaccaceae pro parte, Polygonaceae, Piperaceae, Chloranthaceae pro parte, Myristicaceae, Monimiaceae pro parte, Laurineae, Hernandiaceae, Thymelaeaceae pro parte (rare), Loranthaceae pro parte, ***Myzodendron*** (short prosenchyma resembling rod-cells), Euphorbiaceae pro parte, Balanopseae pro parte, Ulmaceae pro parte, Cannabineae, Moraceae, Urticeae, Leitnerieae, Juglandeae pro parte, Cupuliferae pro parte, Salicineae.

In the ensuing list of Orders and genera, the **prosenchymatous ground-mass of the wood is provided with distinct bordered pits**: Dilleniaceae, Calycanthaceae, Magnoliaceae, Trochodendraceae, Lactoridaceae, ***Eupomatia***, Menispermaceae, Berberideae pro parte, Cistineae pro parte, Canellaceae, Bixineae pro parte, Tremandreae pro parte, Polygaleae, Trigoniaceae, Tamariscineae pro parte, Elatineae, Hypericineae pro parte, Guttiferae pro parte, Ternstroemiaceae pro parte, Dipterocarpeae pro parte, ***Ancistrocladus***, Chlaenaceae, Sterculiaceae pro parte, Lineae pro parte, Humiriaceae, Zygophylleae, Simarubaceae pro parte, ***Koeberlinia***, Ochnaceae pro parte, Chailletiaceae, Olacineae, Ilicineae, Cyrilleae, Celastrineae (occasionally side by side with prosenchyma bearing simple pits), Hippocrateaceae, Stackhousieae (side by side with prosenchyma bearing simple pits), Staphyleaceae pro parte, Sabiaceae pro parte, Rosaceae pro parte (in most cases), Crossosomataceae, Saxifragaceae pro parte, ***Penthorum***, Droseraceae, Hamamelideae, ***Myrothamnus***, ***Ostrearia***, Bruniaceae, Rhizophoraceae pro parte (Legnotideae), Combretaceae pro parte, Myrtaceae sens. str., Melastomaceae pro parte, Loaseae pro parte, Turneraceae pro parte, Passifloraceae pro parte, Cornaceae pro parte, Caprifoliaceae pro parte, Rubiaceae pro parte, Dipsaceae pro parte, Goodeniaceae, Campanulaceae, Vacciniaceae (side by side with prosenchyma bearing simple pits), Ericaceae (in part side by side with prosenchyma bearing simple pits), Epacrideae, Diapensiaceae pro parte, Ebenaceae, ***Brachynema***, Styraceae, Oleaceae pro parte, Apocynaceae pro parte, Asclepiadeae pro parte, Loganiaceae pro parte, ***Desfontainea***, Gentianeae pro parte, Hydrophyllaceae, Boragineae pro parte, Convolvulaceae,

Solanaceae pro parte, Columelliaceae, Selagineae pro parte, Illecebraceae (in most cases), Phytolaccaceae pro parte, Batideae, Nepenthaceae, Aristolochiaceae, Chloranthaceae pro parte, Monimiaceae pro parte, Gomortegaceae, Proteaceae, Thymelaeaceae (in most cases), *Gonystylus*, Penaeaceae, *Geissoloma*, Elaeagnaceae, Loranthaceae pro parte, Santalaceae, *Champereia*, *Grubbia*, Euphorbiaceae pro parte, Daphniphyllaceae, Buxaceae, Balanopseae pro parte, Ulmaceae pro parte, Platanaceae, Juglandeae pro parte, Myricaceae, Casuarineae, Cupuliferae pro parte (in most cases), Lacistemaceae, Empetraceae.

Septate wood-prosenchyma has been observed in certain Berberideae, Violarieae, Bixineae, Pittosporeae, Vochysiaceae, Ternstroemiaceae, Dipterocarpeae, Malvaceae, Tiliaceae, Lineae, Malpighiaceae, Geraniaceae, Simarubaceae, Burseraceae, Meliaceae, Celastrineae, Ampelidaceae, Sapindaceae, Staphyleaceae, Sabiaceae, Anacardiaceae, Connaraceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae, Saxifragaceae, Combretaceae, Melastomaceae, Lythrarieae, Onagrarieae, Samydaceae, Turneraceae, Passifloraceae, Begoniaceae, Cacteae, Araliaceae, Cornaceae, Caprifoliaceae, Rubiaceae, Compositae, Lobeliaceae, Vacciniaceae, Myrsineae, Oleaceae, Loganiaceae, Polemoniaceae, Solanaceae, Scrophularineae, Gesneraceae, Bignoniaceae, Acanthaceae, *Zombiana*, Verbenaceae, Labiatae, Phytolaccaceae, Polygonaceae, Piperaceae, Chloranthaceae, Myristicaceae, Monimiaceae, Laurineae, Euphorbiaceae, Moraceae, Cupuliferae, Salicineae.

A gelatinous layer has been recorded in certain Calycanthaceae, Violarieae, Bixineae, Lineae, Simarubaceae, Hippocastanaceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae (Amygdaleae), Myrtaceae, Onagrarieae, Ebenaceae, Laurineae, Piperaceae, Proteaceae, Euphorbiaceae, Ulmaceae, Moraceae, Casuarineae, Cupuliferae and Salicineae; this feature is often found only in a small number of the wood-fibres composing a piece of wood (cf. also De Bary, Vergl. Anat., p. 497; and Potter, in Annals of Bot., 1904, p. 121 et seq.).

§ 45. Wood-parenchyma. The scanty or abundant occurrence of wood-parenchyma is of considerable systematic value, sometimes even constituting an ordinal character; when present in large quantities, the wood-parenchyma generally forms tangential bands (known as the 'metatracheal' parenchyma in contrast to the 'paratracheal' parenchyma, aggregated round about the vessels), as seen in a transverse section of the branch. For the purposes of specific diagnosis it is also well to take note of the occurrence of scattered wood-parenchyma between the wood-fibres and in the autumn-wood of species forming annual rings. The occurrence of 'chambered crystal-parenchyma' (i.e. parenchymatous strands, divided by means of transverse walls into chambers, which are for the most part of approximately equal size and contain solitary crystals[1]) in the wood is generally only of specific value.

Abundant development of the wood-parenchyma has been observed in the following Orders and genera respectively: Dilleniaceae, Magnoliaceae, Anonaceae, Vochysiaceae, Hypericineae, Guttiferae, Dipterocarpeae, *Ancistrocladus*, Chlaenaceae, Malvaceae, Sterculiaceae, Tiliaceae, Rhaptopetalaceae, Lineae, Malpighiaceae, Simarubaceae, *Balanites*[2], Olacineae, Celastrineae, Sapindaceae, Papilionaceae, Caesalpinieae, Chrysobalaneae, Combretaceae, Lecythidaceae, Rubiaceae, Sapotaceae, Ebenaceae, Boragineae, Verbenaceae, Aristolochiaceae, Laurineae, Proteaceae, Thymelaeaceae, Euphorbiaceae, Moraceae, Juglandeae, Casuarineae, Cupuliferae.

§ 46. Medullary Rays of the Wood[3]. The most important systematic characters are the appearance of the medullary rays in a tangential section, and the breadth of the rays; in determining the latter feature it is necessary to examine both transverse *and* tangential sections. The varied appearance

[1] Clustered crystals rarely occur in the wood-parenchyma (Guttiferae: *Garcinia dioica*, Bl.), while raphides have been observed in this tissue in members of the Dilleniaceae and Ternstroemiaceae.

[2] According to Van Tieghem, Ann. sc. nat., sér. 9, t. iv, 1906.

[3] Essner, Diagnost. Wert der Anz. u. Höhe d. Markstr. bei d. Coniferen, Halle, 1882; Schulz, Markstrahlgewebe, Jahrb. Berliner Gart., ii, 1883, p. 224 and Tab. vii; Michael, Bau d. Holzes der Compositen, etc., Diss., Leipzig, 1885; Zache, Anz. u. Gr. d. Markstr. bei einig. Laubh., Zeitschr. f. Naturw. f. Sachsen u. Thür., 1886, p. 1; Kny, Markstr. dicotyl. Gew., Sitz.-Ber. deutsch. bot. Gesellsch., 1890, p. 176; Herbst, Markstr., Bot. Centralbl., 1894, i, p. 257 et seq., especially p. 409.

of the medullary rays in a tangential section is due to the fact that the component cells either show palisade-like elongation in the vertical direction (upright cells) or radial elongation (horizontal cells), the rays being composed either of both or only of one of these two forms of cells. The degree of elongation of the cells in the vertical or radial direction varies. It is very rare (certain Malvaceae and Passifloraceae) to find medullary rays, in which the cells are compressed in the radial direction, so that they appear strikingly broad (in the tangential direction) in a transverse section of the branch, but narrow and upright in a radial longitudinal section. Tracheidal cells provided with bordered pits have not been observed in the medullary rays of Dicotyledons, being confined to Conifers. An exceptional development in the height of the entire complex of medullary rays often goes hand in hand with the differentiation of broad rays, especially among lianes, but occasionally also in plants which are not lianes (e.g. Urticaceae). For the systematic value of the number of the medullary rays, see §42, p. 1136. The absence of medullary rays is no uncommon feature among herbaceous plants, but occurs also in certain woody plants. In the latter case it is sometimes only rays of the parenchymatous type that are wanting, the cells of the medullary rays being differentiated as short fibrous cells, so that the resulting rays are not very prominent. It remains to mention the penetration of sclerosed tissue, belonging to the medullary rays of the cortex, into the medullary rays of the wood in certain Menispermaceae, Hippocrateaceae, Platanaceae, Casuarineae and Cupuliferae; this phenomenon goes hand in hand with a sinuation of the edge of the cambium, the convexities of which are directed towards the pith.

Broad medullary rays have been observed **in the wood** in certain species of the following Orders and genera: Ranunculaceae, Dilleniaceae, Magnoliaceae, *Menispermaceae, *Berberideae, Capparideae, *Violarieae, Portulaceae, Ternstroemiaceae, Malvaceae, Sterculiaceae, Tiliaceae, Simarubaceae, *Koeberlinia*, *Balanites*, Chailletiaceae, Ilicineae, *Hippocrateaceae, Corynocarpaceae, *Ampelidaceae, Sabiaceae, Coriarieae, Papilionaceae, Caesalpinieae, Rosaceae, Saxifragaceae, Rhizophoraceae, Passifloraceae, Papayaceae, *Cucurbitaceae, *Begoniaceae, Araliaceae, Compositae, Myrsineae, Salvadoraceae, Verbenaceae, Labiatae, Phytolaccaceae, Batideae, *Aristolochiaceae, *Piperaceae, Chloranthaceae, Monimiaceae, Proteaceae, Loranthaceae, Ulmaceae, Moraceae, Urticeae, Platanaceae, Casuarineae, Cupuliferae. Those Orders, which are provided with a *, have broad primary and secondary rays, traversing the entire length of the internodes in the form of continuous plates and dividing up the xylem-mass into narrow segments (H. Schenck's '*Aristolochia*-type').

The **absence of parenchymatous medullary rays** has been demonstrated in certain woody species belonging to the following Orders and genera: Cruciferae, Cistineae, Frankeniaceae, Caryophylleae, Portulaceae, Tamariscineae, Geraniaceae, Stackhousieae, Crassulaceae, Ficoideae, Compositae, Epacrideae, Diapensiaceae, Gentianeae, Boragineae, Scrophularineae, Orobanchaceae, Plantagineae (secondary medullary rays), Nyctagineae, Illecebraceae, Amarantaceae, Chenopodiaceae, Phytolaccaceae, Polygonaceae, Laurineae (*Cassytha*), *Myzodendron* (Sect. *Gymnophyton*). See also Schwendener, Mech. Prinzip, p. 148 et seq.

§ 47. Special Elements found in the Normally Developed Xylem-mass. **Unlignified tissue composed of thin-walled cells** very commonly accompanies the primary tracheae in the protoxylem [1], and must not be confounded with intraxylary soft bast (see § 57). A more important systematic feature lies in the occurrence of unlignified tissue in the secondary xylem of

[1] 'Intraxylary Cambiform' according to Raimann, in Sitz.-Ber. Wiener Akad., xcviii, Abt. 1, 1889; 'primäres Vasalparenchym' according to Strasburger, Leitungsb., 1891; 'parenchyme intraligneux' according to Prunet, in Ann. sc. nat., sér. 7, t. xiii, 1891, p. 362; 'endoxyle' or 'région endoxylaire' according to Briquet, in Atti Congresso bot. internaz., 1892.

woody plants. In certain species of *Vella* and *Brassica* (Cruciferae, Fig. 16, p. 65), *Acanthophyllum* (Caryophylleae) and *Astragalus* (Papilionaceae) it is differentiated (like the soft bast in species exhibiting the anomaly known as successive zones of growth) in the form of concentric rings, and contains numerous tracheae, having small lumina and showing spiral to reticulate thickening. Similar concentric layers of unlignified tissue, which surround the vessels and alternate with prosenchymatous layers devoid of vessels, are developed in certain Crassulaceae; in other members of this Order the unlignified tissue enveloping the vessels forms islands, which occasionally show a concentric arrangement in the fibrous ground-mass of the wood (in which no vessels are found), or composes the entire tissue of the xylem. The latter type of structure is characteristic also of the soft stems of the Papayaceae. The small groups of thin-walled cells in the wood of *Olinia* (Lythrarieae) include crystal-sacs. It remains to make special mention of the appearance of the transverse section through the wood in the species of *Myzodendron*, belonging to the section *Eumyzodendron* (Fig. 178, p. 735), the wood in these species showing a peculiar distribution of the thin-walled tissue, the tracheae, and the wood-prosenchyma. Apart from the cases already mentioned, unlignified tissue has been observed in the xylem of certain woody species (which exhibit normal structure), belonging to the following Orders: Portulaceae, Malpighiaceae, Ampelidaceae, Papilionaceae, Caesalpinieae, Combretaceae, Apocynaceae, Asclepiadeae, Convolvulaceae, Phytolaccaceae, Urticaceae; unlignified tissue is very commonly developed in lianes, showing anomalous structure. Other kinds of special elements, which have been observed in the wood, are: the short prosenchymatous cells of certain Papilionaceae (Fig. 60, p. 275), which have a special shape, and are provided with wide lumina and sieve-like end-walls; and the special barrel- or spindle-shaped cells of certain Cacteae (Fig. 91, p. 410), which show annular thickenings or are provided with a spiral band.

For the rare occurrence of secretory receptacles in the wood, see § 14 (secretory cells), § 16 (mucilage-cavities), § 17 (mucilage-canals) and § 19 (secretory canals).

§ 48. Axial Wood and Wood showing a Tier-like Structure. **Axial wood** (central wood or ring wood) is widely distributed in lianes, belonging to a large number of different Orders; it forms the innermost annular portion of the secondary xylem, and contains vessels, which only have small lumina, so that it is distinctly marked off from the later growth of the wood (periaxial wood) [1].

A xylem-mass, showing a tier-like structure, has been recorded by Höhnel[2] and other authorities in certain Malvaceae, Sterculiaceae, Zygophylleae, Simarubaceae, Meliaceae, Sapindaceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae, Combretaceae, Ebenaceae, and Bignoniaceae; in the Zygophylleae and Caesalpinieae it is of almost universal occurrence. In the wood from the stem of these species delicate transverse lines, which are occasionally somewhat undulated, can be recognized on the surface of a tangential section even with the naked eye or with the help of a lens. The cause of this phenomenon is mostly to be found in the horizontal seriation of the medullary rays, which are all of approximately equal height, each ray arising from a single cell of the cambium. In other cases it is due to a tier-like arrangement of the fibrous cells of the wood or of the pitted areas on these elements, or both of these causes may be combined (for details, see loc. cit.).

[1] Cf. H. Schenck, Anat. d. Lianen, 1893, p. 3.

[2] Höhnel, in Sitz.-Ber. Wiener Akad., lxxxix, Abt. 1, 1884, p. 30, and Sitz.-Ber. deutsch. bot. Gesellsch., 1884, p. 2.

§ 49. Periderm with Special Reference to the Cork[1]. In employing the characters of the cork for taxonomic purposes we have firstly to take into consideration the **place of origin** of the first layer of cork, and **secondly** the detailed structure of the cork-cells. The place of development of the cork in the subaerial parts of the axis[2] is occasionally (although there are generally a few exceptions) characteristic of entire Orders or even of groups of Orders, while in other cases it at least serves to distinguish genera; the cork arises either in a superficial position (i.e. in the epidermis or in the subepidermal layer, or at least in a superficial layer of the primary cortex) or in the interior (i.e. in a deeper cell-layer) of the primary cortex or in the pericycle (when primary hard bast is present, on its inner side). When the cork is formed in a superficial position, its exact place of origin (the epidermal or subepidermal layer of cells, the subepidermal layer or a somewhat deeper layer of primary cortical cells) generally varies from species to species; in some cases, however, the development of the cork from a definite layer is characteristic of the genus (e.g. in *Salix* and *Populus*, see also the Thymelaeaceae), while in other cases it differs even in different specimens of one and the same species. The formation of the cork is particularly irregular in certain species of the Papilionaceae, in which the cork-cambium may develop in the first to the sixth cell-layer of the primary cortex. A further irregularity in the development of the cork has been observed in certain Menispermaceae and Convolvulaceae; here the different parts of the ring of phellogen arise in different positions along the circumference of the branch, viz. at some points in the epidermis, at other points in a deeper cell-layer of the primary cortex, and so on. A similar phenomenon is shown by many plants with reduced leaves[3], where it allows of the retention of the assimilatory tissue of the stem for a considerable length of time. It remains to mention the occurrence of rings of cork in the wood of *Sedum populifolium*, and in the pith of species of *Campanula* and *Phyteuma*[4].

Superficial development of the cork has been observed in the following Orders and genera respectively: Dilleniaceae pro parte, Calycanthaceae, Magnoliaceae, Trochodendraceae, Anonaceae, Menispermaceae pro parte, Berberideae pro parte, Capparideae pro parte, Cistineae pro parte, Canellaceae, Bixineae pro parte, Pittosporeae pro parte, Tremandreae, Polygaleae, Vochysiaceae pro parte, Frankeniaceae, Caryophylleae (rare), Tamariscineae pro parte, Hypericineae, Guttiferae, Ternstroemiaceae pro parte, *Strasburgeria*, *Microsemma*, Dipterocarpeae, *Ancistrocladus* pro parte, *Lophira*, Malvaceae, Sterculiaceae, Tiliaceae, Rhaptopetalaceae, Lineae, Humiriaceae, Malpighiaceae, Zygophylleae pro parte, Geraniaceae pro parte, Rutaceae, Simarubaceae (excl. *Suriana*), Ochnaceae, Luxemburgiaceae, *Wallacea*, Burseraceae, Meliaceae, Chailletiaceae, Olacineae, Octocnemaceae, Ilicineae pro parte, Celastrineae pro parte, Hippocrateaceae pro parte, Pentaphylacaceae, Corynocarpaceae, Rhamneae, Ampelidaceae pro parte, Sapindaceae pro parte (almost always), Didiereae, Hippocastanaceae, Aceraceae pro parte, Staphyleaceae, Sabiaceae, Anacardiaceae, Coriarieae, Connaraceae, Papilionaceae pro parte, Caesalpinieae, Mimoseae, Rosaceae pro parte, Saxifragaceae pro parte, Crassulaceae, Hamamelideae, Bruniaceae, Rhizophora-

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[1] Sanio, in Pringsheim Jahrb., ii, 1860, p. 39 et seq.; De Bary, Vergl. Anat., 1877, pp. 114 and 560 et seq.; Höhnel, in Sitz.-Ber. Wiener Akad., lxxvi, Abt. 1, 1877, p. 507 et seq.; Ross, Periderma, Malpighia, iii and iv, sep. copy, 1890, 67 pp.; Möller, Rindenanat., 1882; Douliot, in Ann. sc. nat., sér. 7, t. x, 1889; J. E. Weiss, in Denkschr. bayer. bot. Gesellsch., Regensburg, vi, 1890, 69 pp., 1 Tab.; Segerstedt, in Bihang Sv. Vet. Akad. Handl., xix, Afd. iii, n. 4, 86 pp., 3 Tab., abstr. in Bot. Centralbl., 1896, i, p. 154.

[2] We may point out here that in one and the same species the place of development of the cork is frequently different in the subaerial parts of the axis and in the subterranean organs (rhizomes and roots). Not uncommonly the cork arises superficially in the subaerial parts, while in the subterranean parts its development is pericyclic; the latter is altogether the rule in roots.

[3] Ross, in Ber. deutsch. bot. Gesellsch., 1886, p. 362, and in Nuovo Giorn. bot. Ital., xxi, 1889; see also Ross, Ass. Gew., etc., Diss., Freiburg i. Br., 1887.

[4] For similar formations of cork in the root of species of *Gypsophila*, *Thapsia*, *Rumex*, *Tragopogon*, &c., see Maheu et Combes, Formations subéro-phellodermiques anormales, Bull. Soc. bot. de France, 1907, pp. 429-42.

ceae, Combretaceae pro parte, Myrtaceae pro parte, Lecythidaceae, Melastomaceae pro parte, Lythrarieae (very rare), *Trapa*, Samydaceae, Turneraceae, Passifloraceae pro parte, Begoniaceae, Cacteae, Umbelliferae pro parte, Araliaceae, Cornaceae, Caprifoliaceae pro parte, Rubiaceae pro parte, Valerianeae pro parte, Dipsaceae pro parte, Compositae, Goodeniaceae pro parte, Lobeliaceae, Diapensiaceae pro parte, Plumbagineae, Primulaceae pro parte, Myrsineae, Sapotaceae, Ebenaceae pro parte, Styraceae pro parte, Oleaceae pro parte, Salvadoraceae, Apocynaceae, Asclepiadeae, Loganiaceae pro parte (Loganioideae, *Polypremum* and *Peltanthera*), Hydrophyllaceae, Boragineae pro parte, Convolvulaceae, Nolaneae, Solanaceae pro parte, Scrophularineae pro parte, Gesneraceae pro parte, Bignoniaceae pro parte, Pedalineae, Acanthaceae pro parte, Myoporineae, *Zombiana*, Selagineae pro parte, Verbenaceae pro parte, Labiatae pro parte, Plantagineae pro parte, Nyctagineae pro parte, Illecebraceae pro parte, Amarantaceae, Chenopodiaceae pro parte, Basellaceae, Phytolaccaceae, Polygonaceae pro parte, Aristolochiaceae, Piperaceae, Myristicaceae, Monimiaceae, Laurineae, Hernandiaceae, Proteaceae, Thymelaeaceae, *Octolepis*, *Gonystylus*, *Geissoloma*, Elaeagnaceae, Loranthaceae, Santalaceae, *Myzodendron*, *Champereia*, *Grubbia*, Euphorbiaceae pro parte, Buxaceae pro parte, Balanopseae, Ulmaceae, Moraceae, Urticeae pro parte, Platanaceae, Leitnerieae, Juglandeae, Myricaceae, Cupuliferae, Salicineae, Lacistemaceae.

Internal development of the cork, i.e., from a deeper layer of cells, which is still, however, situated **in the primary cortex**, is found in the following Orders and genera: Dilleniaceae pro parte, Menispermaceae pro parte, Berberideae pro parte, Cruciferae pro parte, Capparideae pro parte, Cistineae pro parte, Bixineae pro parte, Pittosporeae pro parte, Vochysiaceae pro parte, Tamariscineae pro parte, Ternstroemiaceae pro parte, *Ancistrocladus* pro parte, Geraniaceae (*Tropaeolum*), *Suriana* (Simarubaceae), Ilicineae pro parte, Cyrilleae (pericyclic ?), Celastrineae pro parte, Hippocrateaceae pro parte, Aceraceae pro parte, Melianthaceae, Papilionaceae pro parte, Rosaceae pro parte, Combretaceae pro parte ?, Myrtaceae pro parte, Lythrarieae pro parte, Passifloraceae pro parte, Cucurbitaceae, Ficoideae, Rubiaceae pro parte, Oleaceae pro parte, *Desfontainea*, Gentianeae (pericyclic ?), Polemoniaceae pro parte ?, Boragineae pro parte, Bignoniaceae pro parte, Verbenaceae pro parte, Labiatae pro parte, Plantagineae pro parte, Nyctagineae pro parte, Chenopodiaceae pro parte, Euphorbiaceae pro parte, Urticeae pro parte.

Pericyclic development of the cork has been observed in: Ranunculaceae, Dilleniaceae pro parte, Berberideae pro parte, Cruciferae pro parte, Cistineae pro parte, Bixineae pro parte, Pittosporeae pro parte, Vochysiaceae pro parte, Caryophylleae pro parte, Hypericineae pro parte, Ternstroemiaceae pro parte, *Ancistrocladus* pro parte, Zygophylleae pro parte, *Koeberlinia*, Ampelidaceae pro parte (in the bast ?), Sapindaceae pro parte, Papilionaceae pro parte, Rosaceae pro parte, Saxifragaceae pro parte, Combretaceae pro parte, Myrtaceae pro parte, Melastomaceae pro parte, Lythrarieae pro parte, Onagrarieae (excl. *Trapa*), Loaseae, Umbelliferae pro parte, Caprifoliaceae pro parte, Rubiaceae pro parte, Valerianeae pro parte, Dipsaceae pro parte, Goodeniaceae pro parte, Campanulaceae, Lobeliaceae, Vacciniaceae, Ericaceae, Epacrideae, Diapensiaceae pro parte, Primulaceae pro parte, Ebenaceae pro parte, Styraceae pro parte, Loganiaceae (most Buddleioideae), Polemoniaceae pro parte, Boragineae pro parte, Solanaceae pro parte, Scrophularineae pro parte, Columelliaceae, Gesneraceae pro parte, Acanthaceae pro parte (really endodermal), Selagineae pro parte, Labiatae pro parte, Illecebraceae pro parte, Chenopodiaceae pro parte (see p. 1029), Batideae, Polygonaceae pro parte, Nepenthaceae, Peracaceae, Euphorbiaceae pro parte, Buxaceae pro parte, Empetraceae[1].

In the case of **repeated development of cork** on the same axis, the arrangement of the successive cork-cambia with reference to one another, and the resulting mode of formation of the **bark** (whether scale- or ring-bark), afford characters, which are of systematic value; as a rule, however, these features can only be determined in axes of some thickness, and not in herbarium-material. Ring-bark is found only in species, in which the first phellogen appears in a relatively deep layer of cells. The peculiar repeated development of cork in the Sapindaceous genera *Dodonaea* and *Distichostemon* and some

[1] Pericyclic development of the cork is prevalent in herbaceous plants and in plants having an ericoid habit.

other plants, and the lamellated or tier-like cork of certain Saxifragaceae, Rubiaceae, Loganiaceae (Fig. 125, p. 544), and Labiatae (which is due to repeated development of cork), still require a more detailed discussion; both of these features can be recognized already in the branches of herbarium-material. In *Dodonaea* and *Distichostemon* the development of the cork commences in the pericycle on the inner side of the ring of pericyclic sclerenchyma, and is accompanied by the formation of a many-layered phelloderm; subsequently, a fresh development of cork takes place internal to a second ring of sclerenchyma, which arises at the inner limit of the phelloderm, and so on; similar features are found also in species of *Columellia* (Columelliaceae) and in species of *Rosmarinus* and *Salvia* (Labiatae). In the formation of the **lamellated cork** consecutive layers of the primary cortex develop from without inwards into cork-cambia, each of which gives rise only to a very small number of layers of cork-cells; as a consequence, the rows of cork-cells belonging to the individual tiers do not correspond with one another in the radial direction.

The **detailed structure of the cork-cells** varies, but is frequently only of value for specific diagnosis. The walls of the cells are either (*a*) thin, the cells in this case frequently having very wide lumina (spongy cork), and at the same time often being considerably elongated in the radial direction, or (*b*) thick, in which case the cells are compressed in various ways, often showing a very marked radial compression (tabular cork), or (*c*) sclerosed (stone-cork). In the latter case the cork-cells are either uniformly sclerosed, or the process of sclerosis affects only one side of the cell, or merely a horseshoe-shaped piece of the wall; in the second case sclerosis is confined either to the outer or to the inner tangential walls. The sclerosed cells either compose the entire cork or are confined to certain layers or occur as isolated elements in the cork. In certain species of *Croton* (Euphorbiaceae) the structure of the walls of the cork-cells is particularly noteworthy, since the inner tangential walls are encrusted with small crystals of oxalate of lime, while in *Liquidambar* (Hamamelideae) the cells of the cork are partly silicified. In certain plants, moreover, the cork contains unsuberized cells having walls, which consist of cellulose or are even more or less lignified ('**phelloid-cells**')[1].

The occurrence of layers of phelloid-cells ('Trennungsphelloide' of Höhnel), alternating with one or more, sometimes even a large number, of layers of cork-cells, is of considerable taxonomic value; smaller systematic value is to be attributed to the often abundant occurrence of phelloid-cells ('Massen-' or 'Ersatzphelloid') in thick masses of cork, the strong development of which is frequently only a local phenomenon. Layers of phelloid-cells have been recorded in the following Orders: Hypericineae, Burseraceae (phelloid-cells with silicified inner tangential walls!), Rosaceae, Combretaceae, Myrtaceae, Melastomaceae, Lythrarieae, Onagrarieae, Caprifoliaceae[2], Penaeaceae. The species involved are, in almost all cases, such as show internal development of the cork.

A cork containing phelloid-cells is related to the '**mucilaginous cork**,' which has been observed in certain desert-plants belonging to the Orders Papilionaceae, Chenopodiaceae, and Polygonaceae[3].

At this point we may also refer to the structure of the cork in the Epacrideae, in which the cells do not show a distinct radial arrangement. The development of the cork in this case still requires further investigation.

Contents of a special kind are found **in the cells of the cork** in *Adesmia* (Papilionaceae), *Sarcocaulon* (Geraniaceae) and *Betula* (Cupuliferae). Cork-cells having wide lumina often contain nothing but air; in other cases one finds remnants of the dead cell-contents, which are frequently coloured brown by phlobaphenes.

[1] See Höhnel, loc. cit., p. 595, and J. E. Weiss, loc. cit., p. 6. [2] See Höhnel, loc. cit.
[3] See Jönsson, Anat. Bau der Wüstenpflanzen, Lunds Universitets Årsskrift, xxxviii, Afd. 2, n. 6, 1902.

The **thickness of the cork** can also to a certain extent be employed for systematic purposes. With regard to this point, we may note that strong local proliferations of cork in the form of tubercules, ridges, &c., which are visible to the naked eye [1], have long been taken into consideration.

The **development of phelloderm** [2] is a very widely distributed feature, although as a general rule of little taxonomic interest. In many cases the phelloderm does not differ in any way or only to a slight extent from the tissue of the primary cortex, and under these circumstances it can only be recognized as phelloderm, if its course of development is studied. In other cases, however, it is readily identified owing to the radial arrangement of its cells. The phelloderm is sometimes completely or partially sclerosed. That of *Canella*, for instance, is very characteristic, being composed of radially arranged cells, the inner tangential and radial walls of which are sclerosed.

A point, which has hitherto received too little attention, as far as its taxonomic application is concerned, is **the succession of divisions in the cork-cambium**; these divisions, which are parallel to the surface of the cortex, lead to the formation of the cork and phelloderm; Sanio [3] distinguishes the most important types as 'centripetal,' 'centrifugal,' and 'reciprocal.'

The structure of the **lenticels** [4] (cortical pores) likewise requires further attention; they are often present on the branches of herbarium-material and have already been used by systematists in their diagnoses. Two types of lenticels may be distinguished. In those of the first type the tissue of the lenticel consists solely of complementary cells, which remain in rather firm connexion, although separating from one another to a varying extent by the rounding off of their edges. In the lenticels of the second type layers of loosely arranged complementary cells, which are quite distinct from one another and frequently form a powdery mass, alternate with firm and compact layers of thick-walled cells, which are often of the nature of cork-cells.

The development of periderm, lastly, may be postponed for an often considerable length of time [5], and this phenomenon is also of systematic importance. **Late formation of the periderm** occurs in the Orders enumerated below, and is also found prevalently in plants with reduced leaves, which, owing to the reduction of their foliage-leaves, are dependent upon the assimilatory tissue in the primary cortex. In the Visceae (Loranthaceae) and certain Menispermaceae and Papilionaceae (*Oxylobium*), in which cork only develops at a late stage or, as in the case of the Visceae, is never formed at all, its place is taken by what is called a '**cuticular epithelium** [6]'; the latter is constituted by cells of the epidermis and primary cortex, in which the outer

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[1] A synopsis of proliferations of this kind will be found in Barber, in Annals of Bot., vi, 1892, p. 163; the species named in this synopsis belong to the Malvaceae (Bombaceae), Rutaceae, Simarubaceae, Rhamneae, Leguminosae (Papilionaceae, Caesalpinieae, Mimoseae), Rosaceae, Cacteae, Araliaceae, and Euphorbiaceae.

[2] Kuhla, Entsteh. u. Verbreit. des Phelloderms, Bot. Centralbl., 1897, iii, p. 81 et seq.

[3] Sanio, loc. cit., p. 44 et seq.; see also J. E. Weiss, loc. cit., p. 38, and p. 48 under 9 and 10.

[4] Stahl, Entwicklungsgesch. u. Anat. d. Lentizellen, Bot. Zeit., 1863, p. 561 et seq.; Klebahn, Struktur u. Funkt. d. Lentiz., Ber. deutsch. bot. Gesellsch., 1883, p. 113 et seq., and Rindenporen, Diss., Jena, 1884, also in Zeitschr. f. Naturw., xvii, Neue Folge, x, p. 537 et seq.; Devaux, Lenticelles, Ann. sc. nat., sér. 8, t. xii, 1900, p. 1 et seq.

[5] The genera and species, which are mentioned in Möller's 'Rindenanatomie' and in the respective papers by Ross and Damm as showing late development of periderm, belong to the following Orders: Menispermaceae, Polygaleae, Guttiferae, Ternstroemiaceae, Malvaceae, Geraniaceae, Rutaceae, Ilicineae, Celastrineae, Rhamneae, Aceraceae, Staphyleaceae, Papilionaceae, Caesalpinieae, Mimoseae, Rosaceae, Myrtaceae, Araliaceae, Cornaceae, Compositae, Sapotaceae, Oleaceae, Loganiaceae, Scrophularineae, Polygonaceae, Aristolochiaceae, Laurineae, Proteaceae, Loranthaceae, Euphorbiaceae, Buxaceae, Urticaceae.

[6] Damm, Bau mehrjähr. Epid. bei den Dicotyled., Beih. z. bot. Centralbl., xi, 1902, p. 219 et seq. and Tab.

walls become thickened by the formation of cuticular layers. The superficial layer of wax, differentiated in *Acer pennsylvanicum*, L., is closely related to such a cuticular epithelium; in this species of *Acer* the outer epidermal walls and thereupon the lateral and inner walls of the epidermal cells, and ultimately also the walls of the layers of cortical cells, situated internal to the epidermis, in turn become thickened and changed into a wax-like substance, while in other species of *Acer* the epidermis alone undergoes transformation into wax[1]. The peculiar gelatinization of the outer portions of the walls of cells of the epidermis and hypoderm in the stem of *Calligonum* sp. (Polygonaceae)[2] is likewise similar to a cuticular epithelium.

The **formation of suberized tissue without the help of a phellogen** is found in certain Labiatae, and (see above) apparently also in the Epacrideae (in which the cells of the bast undergo suberization from without inwards), as well as in *Asarum* (Aristolochiaceae, in which the primary cortex becomes suberized).

Development of cork in the leaf is rare (*Fabiana*, Solanaceae); for cork-warts on the leaf, see § 39 (p. 1133).

§ 50. Aerenchyma[3]. In certain plants aerenchyma (i.e. a lacunar tissue, composed of living cells with thin unsuberized walls, Fig. 81, p. 374) is produced by the phellogen in place of cork on those parts of the stem and of the older roots, which are submerged or are embedded in wet soil. Aerenchyma is formed only in a moist habitat, and it is possible to induce its development by artificial means. It has been observed in the following Orders: Capparideae, Hypericineae, Papilionaceae, Mimoseae, Melastomaceae, Lythrarieae, Onagrarieae, Labiatae, and Euphorbiaceae. The groups of phelloid-cells, which are found in the cork of certain plants (see § 49, p. 1148) and are provided with intercellular spaces, may be regarded as a simple type of aerenchyma.

§ 51. Primary Cortex[4]. The differentiation of the assimilatory tissue and endodermis, and the occurrence of collenchyma and sclerenchyma provide a number of structural differences, which may be employed for systematic purposes, although only of value for special diagnosis. A **palisade-like differentiation** of the hypodermal tissue is found chiefly among plants with reduced leaves[5], and occasionally goes hand in hand with the development of furrows on the surface of the stem and the restriction of the stomata to the epidermis of these furrows (see Fig. 61, p. 278, and Fig. 186, p. 788); the same type of differentiation is shown also by the wing-like appendages, found on the stems of plants with decurrent leaves. Ordinary **collenchymatous tissue** is of frequent occurrence in the cortex and is restricted either to a hypodermal layer or to a median zone in the primary cortex (see Möller, loc. cit., p. 416 et seq.). Typical collenchyma (of the well-known form, as found in *Begonia* or *Cucurbita*) is rarer; it is found in the same position as the ordinary collenchyma, but may also be developed in the form of strands on the outer side of the bast-groups. Subepidermal collenchyma of the typical kind frequently participates in the formation of the ribs on the stem. In some cases (e.g. in certain Labiatae and Piperaceae) cells of the typical collenchyma may secondarily become sclerosed and thus transformed into elements resembling bast-fibres. As

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[1] Uloth, in Flora, 1867, p. 385 et seq.

[2] Jönsson, in Lunds Univers. Årsskr., xxxviii, Afd. 2, n. 6, 1902, p. 20.

[3] H. Schenck, Aerenchym, in *Pringsheim Jahrb.*, xx, 1889, p. 525.

[4] Regarding the cortex in general, see Vesque, Anat. de l'écorce, Ann. sc. nat., sér. 6, t. ii, 1875, p. 82; *Höhnel, Gerberinden, Berlin, 1880*; Müller, *Rinde unserer Laubh.*, Diss., Breslau, 1875; Möller, Rindenanat., 1882.

[5] See Schube, Blattarme Pfl., Breslau, 1885; Eick, Ass. Gewebe armlaub. Gewächse., Diss., Bonn, 1881; Nilsson, Studier öfv. stammen såsom assimiler. org., Göteborgs k. Vetensk. och Vitterhetts Samhälls Handl., 1887; Ross, in Nuov. Giorn. bot. Ital., xxi, 1889, etc.

regards the occurrence of **sclerenchyma**, it is necessary to bear in mind the fact that sclerosis of the primary cortex often sets in only at a late stage, so that it is sometimes impossible to determine this feature adequately in the branches of herbarium-material. Features deserving special consideration are: (*a*) the occurrence of bundles of sclerenchymatous fibres; (*b*) the presence of a ring of stone-cells; (*c*) the presence of cells, which (in a transverse section) are sclerosed in the shape of a U; (*d*) the occurrence of 'cristarque'-cells; and (*e*) the spicular cells and storage-tracheides, already discussed in §§ 9 and 11. We may note that the 'cristarque'-cells (i.e. cells, which are thickened in a U-shaped manner, each of them closely enveloping a single solitary or clustered crystal)[1] occasionally form complete zones ('cristarque'), which are more or less interrupted and coincide either with the first or second cell-layers of the primary cortex or with the endodermis; when such a 'cristarque' is present in the body of the cortex, it sometimes occurs in a corresponding position also in the petiole and the veins of the leaf of the same species. In plants inhabiting damp localities and especially in water-plants the primary cortex contains a system of intercellular spaces, which is often strongly developed.

The **endodermis** (protective sheath, phloeoterma)[2], i.e. the innermost cell-layer of the primary cortex, affords but few anatomical characters. In woody species it is at the best developed only in the young parts of the axis, being differentiated as a starch-sheath and containing amylon. In the different parts of the stem of herbaceous plants it often shows up distinctly owing to the suberization of its radial walls, which are provided with Caspary's dots or lines. The divisions in the endodermal cells (for the most part by means of radial walls), characteristic of many Gentianeae-Gentianoideae, are found not only in the root, but sometimes also in the stem of this group of plants.

The secretions and excretions found in the primary cortex have already been discussed in § 13 et seq.

Typical collenchyma has been observed in certain Malvaceae, Cucurbitaceae, Begoniaceae, Araliaceae, Umbelliferae, Dipsaceae, Compositae, Labiatae (four strands of collenchyma in the four angles of the stem), Amarantaceae, Chenopodiaceae, Phytolaccaceae, Polygonaceae and Piperaceae[3]; quite a special form of collenchyma occurs in the Cacteae (Fig. 90, p. 407). The primary cortex contains complete zones or groups of **sclerenchymatous fibres** or isolated sclerenchymatous fibres, some of which may have developed secondarily from collenchymatous cells, in certain Tremandreae, Pittosporeae, Tamariscineae (in *Fouquiera* there is a peculiar sclerenchymatous zone, which arises in the subepidermal layer of cells and consists of many layers), Polygaleae, Hypericineae, species of *Ancistrocladus*, species of *Lophira*, Simarubaceae, Luxemburgiaceae, Stackhousieae, Papilionaceae, Rosaceae (*Prunus* with fibrous cells, some of which have a horizontal course), Halorageae, Umbelliferae, Plumbagineae, Oleaceae, Asclepiadeae, Loganiaceae, Scrophularineae, Bignoniaceae, Acanthaceae, Verbenaceae, Labiatae, Polygonaceae, Piperaceae, Santalaceae, Euphorbiaceae, and Casuarineae (Fig. 186, p. 788); in plants with reduced leaves (see Fig. 61, p. 278), the sclerenchymatous fibres occasionally form plates, which traverse the entire primary cortex, extending from the epidermis to the bast-groups of the vascular bundles. A **ring of stone-cells** has been observed in the primary cortex in certain Capparideae, Guttiferae, Simarubaceae, Burseraceae, Meliaceae, Anacardiaceae, Saxifragaceae, Melastomaceae, Asclepiadeae, Loganiaceae (*Strychnos*), Bignoniaceae, Monimiaceae, species of *Myzodendron*, Euphorbiaceae, Balanopseae, Moraceae, Salicineae, as well as in *Brachynema*, and (according to Möller, p. 419)

[1] See especially Van Tieghem, Le cristarque dans la tige et la feuille des Ochnacées, Bull. Mus. d'hist. nat., xvi, 1902, p. 266 et seq.; and Van Tieghem, in Ann. sc. nat., sér. 8, t. xvi, 1902, p. 166 et seq., etc.

[2] For the distribution of the endodermis among the Dicotyledons, see Schoute, Stelärtheorie, Jena and Groningen, 1903, pp. 108–32.

[3] See also Schwendener, Mechan. Prinzip, p. 157.

also in certain Apocynaceae and Asclepiadeae; in some of these cases, the ring of stone-cells arises in the phelloderm. **Cells, sclerosed in a U-shaped manner,** are present in the primary cortex in certain Calycanthaceae, Canellaceae, Bixineae, Dipterocarpeae, Simarubaceae, Melastomaceae, Gesneraceae, Buxaceae and Empetraceae. **Cristarque-cells** occur in the Rhaptopetalaceae, Lineae, Simarubaceae (Irvingieae), Ochnaceae (with clustered crystals), Luxemburgiaceae (apparently only in the veins of the leaf), and Octocnemaceae. Parenchymatous cells, provided with ridge-like thickenings, are found in the lacunar cortical parenchyma of *Herpestis Monnieria* (Scrophularineae). Regarding the transformation of the outer cells of the primary cortex (together with the epidermal cells) into a cuticular epithelium or a complete layer of wax, see § 49 (pp. 1149–1150).

§ 52. PERICYCLE[1]. *The term 'pericycle' is on the whole a practical* designation, which is not altogether founded on a developmental basis; it is used to indicate that region of the cortex of the stem, which lies between the innermost cell-layer of the primary cortex (which is sometimes differentiated as a distinct endodermis) and the vascular system (or, to put it more exactly, the bast-groups and the intervening primary medullary rays of the cortex). The pericycle is differentiated in a variety of ways. In some cases it is parenchymatous throughout. When this is the case, the pericyclic region can occasionally (and especially in the cortex of the larger branches) be determined only by tracing the primary medullary rays of the cortex (in a transverse section) outwards in the radial direction up to the point, at which they merge into the tissue of the primary cortex. In other cases the pericycle is distinguished by the development of sclerenchymatous elements and is differentiated as an interrupted or continuous mechanical strengthening ring; under these circumstances the pericycle is generally easily recognized. In a pericycle of this kind, a parenchymatous zone, which resembles the ground tissue, is frequently intercalated between the pericyclic sclerenchyma and the vascular system or rather the bast-groups of the latter; this zone either consists only of a few layers of cells or is strongly developed (e.g. in the Menispermaceae or Cucurbitaceae), and is described as the parenchymatous pericycle; when it is wanting, the sclerenchymatous elements of the pericycle are in direct contact with the bast-groups. The sclerenchymatous pericycle consists either (*a*) of a non-sclerosed parenchymatous region, containing only isolated bast-fibres (primary bast-fibres[2]) or groups of bast-fibres of varying dimensions, or (*b*) of a completely or more or less completely closed ring of bast-fibres, or (*c*) of a completely or more or less completely continuous and composite (i.e. composed of bast-fibres and stone-cells) ring of sclerenchyma.

The differentiation of the sclerenchymatous pericycle may vary in branches of different thickness in one and the same species. Thus in young branches the pericycle is occasionally found to contain a closed ring of bast-fibres, which during the subsequent growth in thickness of the branch becomes broken up into isolated groups of fibres (the latter decreasing in size as secondary

[1] Van Tieghem, in Bull. Soc. bot. de France, 1882, p. 280; Morot, in Ann. sc. nat., sér. 6, t. xx, 1884, p. 217, and Bull. Soc. bot. de France, 1886, p. 203; d'Arbaumont, in Bull. Soc. bot. de France, 1886, p. 141; H. Fischer, Der Pericykel, in Pringsheim Jahrb., xxxv, 1900, pp. 1–27 and Tab. i; Pitard, L'évolution et la valeur anat. et taxinom. du péricycle des Angiospermes, Thèse, Bordeaux, 1901, 197 pp., 5 pl., also in Mém. Soc. sc. phys. et nat. Bordeaux, t. lvi, 1901; see also the further papers by Pitard (in Mém. Bordeaux, lv and lvi, 1900–1) which are cited in this thesis.

[2] The bast-fibres of the sclerenchymatous pericycle (primary bast-fibres) are frequently distinguished from the bast-fibres of the secondary bast (secondary bast-fibres) by their structure (the outline and colour being different, while the walls show a slightly different chemical composition, which is probably connected with the difference in colour). To mention examples, with which every one is familiar, such points of difference are shown by the bast-fibres, which compose the outermost layers of hard bast in the phloem-groups of the lime (which are narrowed outwards in the form of wedges), and which are to be regarded as pericyclic elements, by the isolated groups of bast-fibres in the pericycle of 'Cortex Frangulae,' etc.

growth continues), while parenchymatous tissue penetrates into the gaps thus formed both from the outer and inner sides; this parenchyma is either not sclerosed or becomes more or less completely sclerosed. In this way the thicker axes of one and the same species contain either isolated groups of bast-fibres of varying size or a composite ring of sclerenchyma, which is either interrupted or continuous; in thick branches, moreover, the composite ring of sclerenchyma naturally includes a far larger number of stone-cells than in those which are slightly thinner, while the proportion of bast-fibres as compared with stone-cells decreases more and more. In the course of further growth in thickness, such a composite and continuous ring of sclerenchyma may again be burst open, unless prior to that it falls a victim to the formation of bark. It remains to mention that the parenchymatous pericycle, found on the inner side of the sclerenchymatous pericycle in some plants, commences to develop only at a certain stage.

In employing the pericycle for systematic purposes, it is of the utmost importance to take due consideration of its progressive development and of the transformations, which it undergoes. The most valuable feature from this point of view has proved to be the composite and continuous ring of sclerenchyma, which is frequently characteristic of entire Orders or genera.

In utilizing the pericyclic sclerenchyma for taxonomic purposes it is, however, necessary to keep in view its physiological importance as a mechanical tissue. Although the ring of pericyclic sclerenchyma does not occur in all Primulaceae, it is nevertheless characteristic of this Order, since it is absent only in those species, which have no need of flexile strength (Westermaier). Among the Cucurbitaceae a strengthening ring is found in the pericycle only in those species, which show no growth in thickness. In succulent plants there is no pericyclic sclerenchyma.

A **composite and continuous ring of sclerenchyma** is found in the pericycle in the following Orders and genera respectively: Ranunculaceae pro parte, Dilleniaceae pro parte, Calycanthaceae pro parte, Magnoliaceae pro parte, Trochodendraceae pro parte, Menispermaceae pro parte, Berberideae pro parte, Capparideae pro parte, Violarieae pro parte, Bixineae pro parte, Tremandreae pro parte, Vochysiaceae pro parte, Tamariscineae pro parte, Hypericineae pro parte, Guttiferae pro parte, Ternstroemiaceae pro parte, *Strasburgeria*, *Lophira*, Tiliaceae pro parte, Lineae pro parte, Humiriaceae, Malpighiaceae pro parte, Zygophylleae pro parte, Geraniaceae pro parte, Rutaceae pro parte (rare), Simarubaceae pro parte, *Koeberlinia*, Ochnaceae pro parte, Burseraceae, Meliaceae (very rare), Olacineae pro parte, Octocnemaceae, Ilicineae pro parte, Celastrineae pro parte, Hippocrateaceae pro parte, Pentaphylacaceae, Rhamneae pro parte, Ampelidaceae pro parte, Sapindaceae (almost always), Hippocastanaceae, Aceraceae pro parte, Sabiaceae pro parte, Anacardiaceae pro parte, Moringeae pro parte, Connaraceae, Papilionaceae pro parte, Caesalpinieae (almost always), Mimoseae pro parte, Rosaceae pro parte, Saxifragaceae pro parte, Hamamelideae, *Ostrearia*, Rhizophoraceae pro parte, Samydaceae pro parte, Passifloraceae pro parte, Datisceae pro parte, Cornaceae pro parte, Caprifoliaceae pro parte, Epacrideae pro parte, Myrsineae pro parte, Ebenaceae pro parte, Styraceae pro parte, Oleaceae pro parte, Salvadoraceae pro parte, Hydrophyllaceae pro parte, Boragineae pro parte, Acanthaceae pro parte, Verbenaceae pro parte, Illecebraceae pro parte, Phytolaccaceae pro parte, Polygonaceae pro parte, Aristolochiaceae pro parte, Piperaceae pro parte, Chloranthaceae pro parte, Monimiaceae pro parte, Laurineae pro parte, Hernandiaceae pro parte, Gomortegaceae, Proteaceae pro parte, *Geissoloma*, Santalaceae pro parte, *Champereia*, *Grubbia* pro parte, Euphorbiaceae pro parte, Balanopseae, Ulmaceae pro parte, Platanaceae, Juglandeae pro parte, Myricaceae pro parte, Casuarineae, Cupuliferae, Lacistemaceae.

The exact nature of the elements composing the pericyclic sclerenchyma, and especially the detailed structure of the bast-fibres (length, structure of the walls and lumina, the kind of pitting [1], and the occurrence of septation), also requires to be taken into account in systematic anatomical researches. In the following cases the arrangement or structure of the elements forming the sclerenchyma-ring is particularly noteworthy: in *Balanites* (Simarubaceae, p. 185), the ring of

[1] Bordered pits occur on the bast-fibres in the Epacrideae.

sclerenchyma consists of a ring of stone-cells, at the inner margin of which groups of bast-fibres are inserted; in certain Calycanthaceae, Guttiferae, Ternstroemiaceae, Simarubaceae (Irvingieae), Chrysobalaneae, Rhizophoraceae, Samydaceae, Salvadoraceae, Monimiaceae, Laurineae, Hernandiaceae, Gomortegaceae and Euphorbiaceae the sclerenchymatous ring contains stone-cells, which are thickened in a U-shaped manner.

§ 53. BAST-GROUPS AND ESPECIALLY THE SECONDARY BAST. The structure of the bast likewise affords an abundance of anatomical characters. These are as follows: (*a*) the occasional prominent demarcation of the bast-groups of the individual vascular bundles (their outline in transverse section in this case resembling that of a symmetrical trapezium, or being convex on its outer side), a feature which goes hand in hand with the occurrence of broad primary (cortical) medullary rays, which often widen out towards the exterior to a marked extent; (*b*) the presence or absence of secondary hard bast, which, when present, is developed in varying amount and shows diverse distribution (solitary **bast-fibres**; groups of bast-fibres with a scattered, reticulate or stratified arrangement) and differentiation (chiefly as regards the length, the appearance in transverse section, the mode of thickening, the thickness of the walls, the size of the lumina and the kind of pitting of the fibres; the latter occasionally also septate or merging into sclerenchymatous parenchyma) of its elements; (*c*) the occurrence of ordinary stone-cells or spicular cells (see § 9); (*d*) the structure of the **sieve-tubes** (the width of their lumina; the diverse differentiation and arrangement of the sieve-plates, viz. either (i) simple sieve-plates (i.e. provided with a single sieve-area), which are mostly situated on horizontal cross-walls, or (ii) scalariform sieve-plates (having from two to many sieve-areas), which are found on strongly inclined division-walls, the latter being seen from the surface in a radial longitudinal section, or (iii) both simple and scalariform sieve-plates side by side; the occurrence of sieve-plates on the lateral walls; and finally, the delicate or coarse nature of the pores in the sieve-plates); (*e*) the breadth of the secondary **medullary rays** and the sclerosis of the parenchyma of the secondary rays between the groups of secondary hard bast, which occasionally leads to the formation of complete sclerenchymatous rings; (*f*) lastly, the occurrence and distribution of the manifold excretions and secretions (see § 13 et seq., especially the occurrence of chambered crystal-fibres, bearing solitary or clustered crystals, i.e. fibre-like groups of cells, with numerous transverse septa, the individual chambers containing deposits of oxalate of lime).

The conditions for the determination of many of these features[1] are frequently very unfavourable in the case of herbarium-material, which is generally alone available for the purposes of a systematic investigation, since the features in question can often only be recognized, when the secondary bast has attained a certain degree of thickness. It is therefore impossible to deal fully with all of the above-mentioned characters.

The following lines, in the first place, contain a list of the Orders and anomalous genera, in which, unless there is a statement to the contrary, **typical secondary hard bast** (i.e. composed of bast-fibres), has been observed; the Orders and genera, in which some of the members at least show a distinct stratification of the phloem into soft and hard bast, are indicated by a *: *Ranunculaceae, Dilleniaceae, *Magnoliaceae, Trochodendraceae, *Anonaceae, Berberideae, Cruciferae, Canellaceae, *Bixineae, Polygaleae, Vochysiaceae ?, *Tamariscineae, *Guttiferae, Ternstroemiaceae, **Microsemma*, *Dipterocarpeae, **Monotes*, Chlaenaceae, *Malvaceae, *Triplochitonaceae, *Sterculiaceae, *Tiliaceae, *Rhaptopetalaceae, *Lineae, Humiriaceae, *Malpighiaceae, Geraniaceae, *Rutaceae, *Simarubaceae, **Balanites*[2], Ochnaceae,

[1] See Möller, Rindenanat., 1882, especially p. 423 et seq.; Lecomte, Liber, Ann. sc. nat., sér. 7, t. x, 1889, p. 192; Perrot, Tissu criblé, Thèse, Paris, 1899, 243 pp.; Hill, Sieve-tubes, Annals of Bot., 1903, pp. 265–7.

[2] According to Van Tieghem, Ann. sc. nat., sér. 9, t. iv, 1906.

*Laxemburgiaceae, *Wallacea*, Burseraceae, *Meliaceae, Olacineae, Octoсnemaceae, Ilicineae (rare), Celastrineae, *Hippocrateaceae, *Rhamneae, *Ampelidaceae, Sapindaceae, Hippocastanaceae, *Aceraceae, Staphyleaceae, *Anacardiaceae, Connaraceae, *Papilionaceae, Caesalpinieae, *Mimoseae, *Rosaceae, Saxifragaceae, Hamamelideae, Combretaceae, *Myrtaceae, Lythrarieae, Onagrarieae, Passifloraceae, *Papayaceae, Datisceae, *Cornaceae, *Caprifoliaceae, Rubiaceae, Compositae, Ericaceae, *Epacrideae, Sapotaceae, Styraceae, *Oleaceae, Apocynaceae, Boragineae, *Bignoniaceae, Acanthaceae, Verbenaceae, Batideae, *Myristicaceae, Monimiaceae, Laurineae, *Proteaceae, *Thymelaeaceae with *Octolepis* and *Gonystylus* (bast-fibres in this case projecting like threads of silk on the ruptured surface, when the dried branches are broken in two), *Elaeagnaceae, Santalaceae, *Grubbia*, *Euphorbiaceae, Buxaceae, *Ulmaceae, Cannabineae, *Moraceae, *Platanaceae (sclerotic parenchyma!), *Leitnerieae, *Juglandeae, Myricaceae, Casuarineae, *Cupuliferae, *Salicineae.

The **following types of bast-fibres deserve special mention** (apart from the special spicular cells occurring in the bast of the axis, and referred to at the end of §9): (*a*) the long bast-fibres, found in many Lineae and Urticaceae, and the strikingly short spindle-shaped bast-fibres of *Berberis*; (*b*) the bast-fibres of many Apocynaceae and Asclepiadeae, which are provided with local enlargements; (*c*) the bast-fibres of certain Vacciniaceae, Ericaceae and Epacrideae (Fig. 111, p. 402), which bear bordered pits; (*d*) the bast-fibres of many Euphorbiaceae, which show a well-marked stratification of their wall; (*e*) the septate bast-fibres, found in many Orders; and lastly, (*f*) the acicular fibres or raphidines, occurring in many Acanthaceae. The raphidines are fibrous cells, which are of small dimensions in a transverse section, and, like the raphides in a raphide-sac, are found in large numbers in long sac-shaped cells of the soft bast, from which they are originally derived by cell-division (Fig. 146, p. 619). Rod-cells, i.e. elongated parenchymatous cells, are frequently developed in the bast in place of bast-fibres. Closed rings of stone-cells have been observed only in the outermost portion of the bast of certain Loganiaceae (species of *Strychnos*) and Asclepiadeae. The structure of the **soft bast** shows noteworthy features in *Podophyllum* (Berberideae), in which, as in the case of Monocotyledons, it consists only of sieve-tubes and companion cells, and in almost all the Gentianeae-Menyanthoideae, which have characteristic groups of small sieve-tubes, these groups being equal in size to a single cell of the neighbouring parenchyma. Sieve-tubes with wide lumina are found chiefly in lianes, while in laticiferous and succulent plants the sieve-tubes are extremely narrow and insignificant. A tendency towards a collenchymatous differentiation of the soft bast has been recorded in the Caryophylleae and allied Orders, as well as in the Pittosporeae and Plantagineae.

Stratification of the bast by means of tangential layers of chambered fibres containing clustered crystals is found in certain Combretaceae, Myrtaceae and Lythrarieae.

VI. Anomalous Structure of the Axis [1].

§ 54. Contracted Vascular Systems of submerged plants and certain other Dicotyledons, and Dissociation of the Ring of Vascular Bundles. The vascular bundles, found in the different parts of the stem of submerged plants [2], fuse to form **axile strands**, in which the individual bundles are generally no longer distinguishable from one another; the only known exception to this rule is constituted by *Ranunculus aquatilis*. In those forms (species of *Peplis* and *Elatine*), which have a type of structure not far removed from that normally found in Dicotyledons, a pith is present within the ring of wood and bast, while in *Peplis*, which belongs to an Order having intraxylary phloem, the latter is likewise found. In *Callitriche* there is a reduced pith, composed only of a small number of cells, which subsequently undergo resorption. *Hippuris*, *Myriophyllum*, *Hottonia*, *Aldrovanda* and *Ceratophyllum* do not possess a true pith; the vascular system in these genera is concentric

[1] The anomalies presented by the structure of the root in part correspond to analogous features in the stem, and, when this is the case, they will be discussed in common with the latter; for the remaining features, see § 64, p. 1168.

[2] H. Schenck, Vergl. Anat. d. subm. Gew., Bibl. bot., Heft 1, 1886, 67 pp. and 10 Tab.

with central xylem. In *Hippuris*, *Myriophyllum* and *Hottonia* the xylem of the concentric vascular strand consists of an apparent pith and of tracheae with intermingled wood-parenchyma; the former is homologous with wood-parenchyma, since the first tracheae, which subsequently become resorbed, develop in the centre of this tissue. In *Aldrovanda* and *Ceratophyllum* (Fig. 189, p. 802) the xylem consists solely of pith-like wood-parenchyma, enclosing a central air-canal, which arises by the resorption of a group of primary tracheae (*Aldrovanda*) or of procambial cells devoid of annular or spiral thickening (*Ceratophyllum*).

Contracted vascular systems, taking the form of a concentric vascular bundle with central xylem, are found also in an undetermined species of *Leiphaimos* (a saprophytic member of the Gentianeae, see p. 550), in certain Cuscuteae (parasitic forms, see p. 573), and in *Peperomia tenera*, Miq., and *Verhuellia* (Piperaceae, the species in question being neither aquatics nor parasites nor saprophytes).

Dissociation of the fibrovascular system and mutual independence of the wood and bast has been observed among the Lentibularieae in *Genlisea* (in the stem and peduncle), *Polypompholyx* (in the vegetative and floral axes) and *Utricularia* (in the axis of inflorescence, *Fig.* 138, p. 595); the groups of wood and bast in these genera are either irregularly scattered or show an annular arrangement, the latter being the case in *Polypompholyx*, in which the groups of soft bast are placed in a ring and alternate with solitary vessels. Here we may no doubt also include those cases, in which the vascular ring contains incomplete bundles in the form of groups of soft bast or (*Bartonia verna*), in addition to these, of groups of vessels side by side with complete bundles (provided with xylem and phloem); this feature has been recorded in certain Cuscuteae and in a saprophytic member of the Gentianeae (*Bartonia verna*). We may finally mention the anomalous structure of the stem in the anomalous genus *Circaeaster*, which is appended to the Chloranthaceae in Bentham and Hooker's Genera Plantarum; the delicate stem in this genus resembles the root in containing a diarch vascular system.

§ 55. Axes showing Polystelic Structure[1]. Van Tieghem has introduced the term 'stele' to designate the ring of vascular bundles, found in the axis of a normal Dicotyledon, together with the pith enveloped by the vascular ring; so that the axis of Dicotyledons as a rule has a monostelic structure. When *the axis shows several steles in a transverse section, it is said to be* polystelic. This structure arises in the following way. The vascular system at the base of the axis is devoid of a pith; in its further course up the stem it becomes band-shaped and divides by a median constriction into two systems; at a higher point in the axis the latter again become band-shaped and the process of division is repeated, and so on. In an axis showing polystelic structure the individual steles are provided with an endodermis and pericycle of their own, while a pith may or may not be present. In a transverse section the steles are either irregularly scattered or show an annular arrangement, while in the vertical direction they anastomose to form a network. In some cases, moreover, they are fused in a transverse section so as to form a ring, which is interrupted at certain points (gamostelic structure, in contrast to the dialystelic arrangement, in which the steles lie isolated in a transverse section).

Whereas polystelic structure is very widely distributed in the axes of

[1] Van Tieghem et Douliot, Polystélie, Ann. sc. nat., sér. 7, t. iii, 1886, p. 275, see also Bull. Soc. bot. de France, 1886, p. 213; Scott, in Ann. of Bot., v, 1891, p. 514; Schoute, Stelärtheorie, Groningen and Jena, 1902, 175 pp.; [Worsdell, Stelar theory, in New Phytologist, 1903, pp. 140–4]; Schindler, in Engler, Bot. Jahrb., xxxiv, 1904, Beibl. 77, p. 67 et seq.; [Hill, Stelar theories, Science Progress, i, 1906, pp. 325–42].

Vascular Cryptogams (among the Ferns and in *Selaginella*, see Leclerc du Sablon, in Ann. sc. nat., sér. 7, t. xi, 1890), it is rare among Dicotyledons. It has been observed in the following cases: in *Victoria regia* (locally) and in the rhizome of certain species of *Nymphaea* (Nymphaeaceae); in the nodes of the stem of *Parnassia* (Saxifragaceae); in the stolons of species of *Gunnera* (Halorageae); in certain Primulaceae (species of *Primula*, belonging to the section *Auricula*, Fig. 115, p. 505, *Bryocarpum* and *Dodecatheon*) and Acanthaceae (species of *Dianthera*)[1]; finally, also in the fruit-stalks of certain Guttiferae, Ternstroemiaceae, Malvaceae, Sterculiaceae, Meliaceae and Moraceae[2]; regarding *Pinguicula* (Lentibularieae), see p. 591[3].

A similar type of vascular structure, which, however, does not fall under the heading of polystely (among other reasons because of the absence of an endodermis around the individual bundles) and might perhaps be described as **apparent polystely,** occurs in certain species of *Leiphaimos* (Gentianeae) and *Christisonia* (Orobanchaceae); in these genera concentric vascular bundles with central xylem are found in the vascular ring. For a similar type of structure, viz. divided xylem-masses, see § 60.

§ 56. Medullary and Cortical Vascular Bundles[4]. A considerable number of Dicotyledons depart from the ordinary type of structure, in the fact that the vascular bundles are not arranged in a simple ring. In some of these plants there are medullary bundles or cortical bundles or both, in addition to the normal ring of vascular bundles; in other cases all the vascular bundles of the axis are arranged in two or more rings, which are sometimes not distinctly marked off from one another, or the bundles, as seen in a transverse section, lie irregularly scattered in the ground tissue. We cannot enter into details here as to the nature (leaf-trace bundles or (rarely) cauline bundles) and course of these vascular strands. From the systematic point of view the features in question are for the most part characteristic of species only and rarely of genera, tribes, or even Orders.

Vascular bundles, which are irregularly scattered in a transverse section of the stem or are arranged in more or less distinctly marked rings, are found in the following genera and Orders respectively: *Actaea, Cimicifuga, Thalictrum* (Ranunculaceae); *Podophyllum* (Fig. 10, p. 46), *Jeffersonia, Diphylleia, Leontice*, etc., see p. 821 (Berberideae); Nymphaeaceae (cf. § 55); *Papaver* (Papaveraceae); *Geranium* (Geraniaceae); Cucurbitaceae; Umbelliferae; *Centaurea, Scorzonera* (Compositae); *Candollea* (Candolleaceae); *Limnanthemum* (Gentianeae, in the axis of inflorescence of the species belonging to the section *Nymphaeanthe*); *Christisonia, Conopholis, Epiphegus* (Orobanchaceae); *Mourera* (Podostemaceae); *Hydnora* (Cytinaceae, in the rhizoid-shoots); *Peperomia* (Piperaceae, Fig. 169, p. 692); *Myzodendron*; Balanophoreae. See also the list of plants with medullary or cortical vascular bundles.

The **medullary vascular bundles**, as seen in a transverse section, are either arranged in one or several rings or are irregularly scattered; it is very rare to find only a single vascular bundle in the centre of the pith. The medullary bundles are either collateral or concentric[5] in structure and are occasionally reduced to small

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[1] According to Holm, Bot. Gaz. xliii, 1907.

[2] These anomalies should perhaps be included in the category of 'divided xylem-masses' (see § 60).

[3] In addition to mono- and polystelic structure of the stem Van Tieghem also distinguishes 'astelic' structure. The structure of the stem is said to be astelic, when the vascular system, found at the base of the stem, becomes dissolved into individual vascular bundles at a higher level, these bundles showing an annular or scattered arrangement in the transverse section and each having its own endodermis and pericycle. Astelic structure has been demonstrated in: Ranunculaceae (*Anemone, Eranthis, Oxygraphis, Ranunculus* incl. *Ficaria*), Nymphaeaceae, *Chelidonium maius* (Papaveraceae), *Byblis* (Droseraceae, peduncle), and *Trifolium* (Papilionaceae).

[4] De Bary, Vergl. Anat., 1877; J. E. Weiss, Markständiges Gefässbündelsyst., Bot. Centralbl., 1883, iii, p. 280 et seq.; Col, Faisceaux médullaires, Journ. de bot., xvi, 1902, pp. 234-55; Col, Disposition des faisceaux, Ann. sc. nat., sér. 8, t. xx, 1904, pp. 1-288; Van Tieghem, Méristèles cort., Ann. sc. nat., sér. 9, t. i, 1905, pp. 33-44.

[5] Möbius, in Ber. deutsch. bot. Gesellsch., 1887, p. 2 et seq

groups of soft bast, bundles of fibres, etc. Medullary bundles showing collateral structure are generally normally orientated (i.e. their xylem lies on the inner, their phloem on the outer side), but in some cases they are inversely orientated (i. e. the phloem lies on the inner side). The concentric medullary bundles have either central xylem or central phloem. The apparent bicollateral bundles of the pith are produced by the fusion of the contiguous xylem-groups of two collateral vascular bundles.

In most cases the medullary vascular bundles are of the nature of leaf-traces; for details, see J. E. Weiss, loc. cit. The vascular bundles or bundles of soft bast, which occur in the pith in members of Orders having intraxylary phloem and are included in the following list, do not, strictly speaking, belong to this category (see also § 57). Some of these medullary bundles are branches of the intraxylary phloem, situated at the margin of the pith, the primary tracheae occasionally (especially in the Melastomaceae) accompanying the phloem in its passage into the pith; in other cases they arise from the intraxylary soft bast, owing to the fact that the cambium of the latter not only produces bast internally, but also woody tissue externally, so that the bundles of soft bast at the margin of the pith become transformed into inversely orientated vascular bundles. For the apparent medullary vascular bundles, which occur in certain Nyctagineae, Amarantaceae and Chenopodiaceae with anomalous structure, see § 59 (p. 1165).

Medullary vascular bundles have been observed in the following Orders and genera respectively: Ranunculaceae (*Anemone, Delphinium, Hydrastis, Glaucidium*); Cruciferae (rhizome of the kohl-rabi and of *Cochlearia Armoracia*, concentric); Vochysiaceae (in *Trigoniastrum*, inversely orientated; phloem-bundles in other members of the Order); Caryophylleae (*Acanthophyllum*, inversely orientated); Sterculiaceae (*Leptonychia*, concentric with central phloem); Luxemburgiaceae (Godoyeae, composed of vessels and fibrous cells or of a phloem-group and fibrous cells); Burseraceae (*Canarium*, inv. orient.); Olacineae (*Jodes*, inv. orient.); Sapindaceae (*Toulicia, Guioa*, and *Mischocarpus*, often reduced to bundles of fibres); Melianthaceae (*Melianthus* and *Bersama*, concentric with central phloem; sometimes reduced to bundles of fibres, Fig. 54, p. 241); Mimoseae (*Elephantorrhiza*, concentric with central phloem); Saxifragaceae (*Saxifraga, Rodgersia, Peltiphyllum*); Melastomaceae (very common, in connexion with the intraxylary phloem; occasionally reduced to phloem-bundles); Onagrarieae (phloem-bundles, in connexion with the intraxylary phloem); Halorageae (*Gunnera*, inv. orient.); Passifloraceae? (*Passiflora*?); Cucurbitaceae (*Coccinia, Cucurbita, Kedrostis, Melothria, Wilbrandia*, inv. orient., in connexion with the intraxyl. phl.—*Siolmatra*, inv. orient., here arising subsequently on the inner side of originally collateral vascular bundles); Begoniaceae (*Begonia*, sometimes concentr. with central phloem); Cacteae (*Mammillaria, Echinocactus, Echinopsis, Cereus*); Umbelliferae (common, in part inv. orient., concentr. with central phloem or apparently bicollateral); Araliaceae (*Aralia* and *Arthrophyllum* with varied orientation of wood and bast, *Aralidium* with bundles of fibres; for the rest, see pp. 431, 946); Compositae (very widely distributed in the Cichoriaceae, here in part reduced to phloem-bundles; rare in other Compositae); Candolleaceae (*Candollea*, see above); Goodeniaceae (*Goodenia, Selliera, Distylis*, penetrating into the normal ring of vascular bundles, Fig. 107, p. 472); Campanulaceae (phloem-bundles common, in part at the margin of the pith; also inv. orient. and concentr. vascular bundles, the latter with central phloem); Plumbagineae (*Statice* and *Acantholimon*, concentr. or inv. orient.); Apocynaceae (in *Willoughbeia* and species of *Apocynum* an inv. orient. ring of vascular bundles, arising from the intraxyl. phloem; not uncommonly also medullary phloem-bundles, as branches of the intraxyl. phloem); Asclepiadeae (*Periploca* with formation of wood from the cambium of the intraxyl. phloem; medullary phloem-bundles, as in the Apocynaceae); Loganiaceae (*Anthocleista* with medullary vascular bundles,—species of *Gelsemium* and *Spigelia* with inv. orient. vascular bundles, arising from the intraxyl. phloem,—in addition to that phloem-bundles, as in the Apocynaceae); Gentianeae (*Gentiana* with medullary vascular bundles or phloem-bundles,—in addition to that phloem-bundles, as in the Apocynaceae); Convolvulaceae (in *Argyreia, Erycibe, Evolvulus, Hewittia, Neuropeltis, Prevostea* and *Stictocardia* an inv. orient. ring of vascular bundles, formed from the intraxyl. phloem; normal medullary vascular bundles in *Rivea*); Solanaceae (*Anthotroche* with a slight formation of wood from the cambium of the intraxyl. phloem; medullary phloem-bundles, as in the Apocynaceae); Orobanchaceae (*Orobanche, Cistanche*); Gesneraceae (*Klugia, Rhynchoglossum, Monophyllaea*, also the tubers of *Coleus*); Bignoniaceae (*Campsis*, inv. orient.); Acanthaceae (*Acanthus*,

Mendoncia, *Pseudocalyx* and *Thunbergia*, inv. orient.); Verbenaceae (*Teijsmanniodendron*); Plantagineae (*Plantago*, cambiform- and phloem-bundles); Nyctagineae (apparent and ? true medullary vascular bundles, common); Amarantaceae (true and apparent medullary vascular bundles); Chenopodiaceae (as in the Amarantaceae); Phytolaccaceae (*Phytolacca*, concentr. with central phloem); Polygonaceae (*Rheum* and *Rumex*, inv. orient., concentr., etc.); Aristolochiaceae (*Aristolochia triangularis*, Fig. 167, p. 686, here as a secondary formation, which only develops after the splitting up of the ring of vascular bundles); Piperaceae (*Piper* incl. *Heckeria* and *Macropiper*, see Fig. 169, p. 692); Thymelaeaceae (*Aquilaria* with secondary development of wood from the serial cambium of the intraxyl. phloem); *Myzodendron* (species of the section *Eumyzodendron*, Fig. 178, p. 735); Balanophoreae; Euphorbiaceae (*Ricinus*); Cupuliferae (*Alnus*, cauline bundles, which are only developed as an exception).

The **cortical vascular bundles**[1] generally have collateral structure, and are then either normally or inversely orientated; cortical bundles with concentric structure are rare, and the same is true of the reduction of cortical bundles to phloem-bundles. Cortical bundles have been found in the following Orders or genera: Ranunculaceae (*Paeonia*); Calycanthaceae (inv. orient. and showing secondary growth, universally distributed, Fig. 3, p. 25); Cruciferae (*Eruca*, *Lepidium*); Violarieae (all Sauvagesieae); Tremandreae (*Tetratheca* with winged band-shaped axes); *Strasburgeria*; Dipterocarpeae (universally distributed); *Lophira*; *Monotes*; Rhaptopetalaceae (two cortical vascular bundles of quite general occurrence); Lineae (*Aneulophus*, *Erythroxylon*); Ochnaceae sens. str. (universally distributed); Luxemburgiaceae (universally distributed); *Wallacea*; Papilionaceae (species with decurrent foliar wings on their axes; species of *Cytisus*, *Genista* and *Retama* with reduced leaves and furrowed stems; *Borbonia* and *Viborgia*; Vicieae); Saxifragaceae (*Peltiphyllum*); Crassulaceae (*Sempervivum*, *Sedum* and *Rochea*, concentr. with central xylem); Droseraceae (*Drosophyllum*, inv. orient.); Lecythidaceae (inv. orient. in the Barringtonieae, normally orient. in the remaining members of the Order); Melastomaceae (common); Turneraceae (*Piriqueta*); Begoniaceae; Cacteae (*Rhipsalis*, *Lepismium*, *Pfeiffera*, and *Phyllocactus*, forming a plexus and showing growth in thickness); Ficoideae (*Mesembryanthemum*, reticulate); Umbelliferae (*Mulinum*, *Siler* and *Eryngium*, in the last genus forming contracted vascular systems composed of several bundles, which have a certain similarity to the peripheral xylem-masses of certain *Serjanias*); Araliaceae (*Oreopanax* and the anomalous genus *Aralidium*, see p. 946); Cornaceae (*Mastixia*); Rubiaceae (*Sickingia*); Compositae (*Achillea*, *Ammobium*, *Anthemis*, *Atractylis*, *Centaurea*, *Cynara*, *Gundelia*, *Helenium*, *Madia*, *Senecio*); Candolleaceae (*Candollea* ?, rightly included here ?, see p. 963, and § 58); Campanulaceae (species of *Campanula*, here concentr. and like those of *Eryngium*; *Lobelia Rhynchopetalum* with concentr. cortical vascular bundles, resembling those of a *Cycas*); Lennoaceae (*Ammobroma*, *Lennoa*); Plumbagineae (*Aegialitis*, *Armeria*, *Limoniastrum*, *Statice*); Primulaceae ('réseau radicifère' in the root-stock of the species of *Primula* of the sections *Auricula* and *Officinales* and of *Bryocarpum* and *Dodecatheon*); Asclepiadeae (rhizome of *Tylophora*); Loganiaceae (*Anthocleista*, concentr.); Gentianeae (Menyanthoideae, viz. *Limnanthemum*, *Menyanthes* and *Villarsia*); Lentibularieae (root-stock of *Pinguicula* with a 'réseau radicifère'); Gesneraceae (*Rhynchoglossum*); Verbenaceae (species with winged stems); Plantagineae (*Plantago*, cambiform-bundles and vascular bundles); Chenopodiaceae (Salsoleae and Salicornieae, in part normally, in part inv. orient.); Polygonaceae (*Calligonum*, Fig. 162, p. 673; *Rumex*, here in the pericycle); Nepenthaceae (*Nepenthes*); Penaeaceae (angles of the stem of *Endonema*); Balanophoreae (see p. 738); Euphorbiaceae (*Euphorbia*); Buxaceae (species of *Buxus*, belonging to the sections *Eubuxus* and *Notobuxus*); Casuarineae (Fig. 186, p. 788).

For the occurrence of sieve-tubes, which are situated outside the limits of the vascular system, in the Cucurbitaceae, see p. 396.

§ 57. INTRAXYLARY PHLOEM[2]. The term 'intraxylary phloem' is here

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[1] For their course, see especially De Bary and J. E. Weiss, ll. cc.

[2] Petersen, Bicoll. Gefässb., in Engler, Bot. Jahrb., iii, 1882, pp. 359–400 and Tab. iv–viii, see also Bicoll. Karbundt, etc., Diss., Copenhagen, 1882; J. E. Weiss, Markst. Gefässbündelsystem, Bot. Centralbl., 1883, iii; Solereder, Holzstr., 1885, p. 27; Hérail, in Ann. sc. nat., sér. 7, t. ii, 1885, p. 267; Lamounette, in Ann. sc. nat., sér. 7, t. x, 1890, p. 193; Scott and Brebner, in Ann. of Bot., v, 1891, p. 259; Van Tieghem, in Journ. de bot., 1891, p. 117; Perrot, Tissu criblé, Thèse,

taken in a general sense to include those groups of soft bast, which are situated internally to the ring of vascular bundles ; in their further course these phloem-groups bend out into the leaves together with the leaf-trace bundles, on the inner side of which they are situated, so that it is possible to trace them in a corresponding position into the petiole and commonly also into the larger or even the finer veins of the leaf. The groups of internal phloem, moreover, appear to be characterized by the fact that they are generally differentiated only at a slightly later stage than the outer phloem-groups.

As a general rule the course of the bundles of intraxylary phloem serves to distinguish them sharply from medullary vascular bundles and medullary phloem-bundles. The medullary phloem-bundles, which are found in the Cichoriaceae and Lobeliaceae and which, in the absence of an investigation of their course, might be regarded as intraxylary phloem, are of an essentially different nature ; they belong to the normally constructed ring of vascular bundles from which groups of phloem bend out secondarily into the pith [1].

The differentiation of the intraxylary phloem varies. It either forms a ring of tissue at the margin of the pith, or appears in the shape of isolated bundles, which vary very much in size (massive or very small) and lie opposite the primary portions of the vascular bundles. In the latter case the intraxylary phloem is either closely apposed to the xylem of the vascular ring, the bundles of which are then said to be bicollateral, or it is separated from the xylem by one or more layers of parenchymatous cells. Portions of the intraxylary phloem may be given off as branches, and these strands of phloem are occasionally (e.g. in many Melastomaceae) accompanied by the primary tracheae, so that phloem-bundles or vascular bundles appear in the middle of the pith (cf. § 56, p. 1158). Hard bast is frequently present at the inner margin of the internal phloem. In many cases, moreover, a cambium develops at the outer boundary of the intraxylary phloem ; this cambium produces secondary soft bast on its inner side and occasionally leads to such an extensive increase of the intraxylary phloem that the innermost portions of the latter become compressed so as to resemble horn-bast. In a few cases (in certain Cucurbitaceae, Apocynaceae, Asclepiadeae, Loganiaceae, Convolvulaceae, Solanaceae, Thymelaeaceae ; regarding this point cf. § 56, p. 1158) this cambium produces xylem on its outer side, so that medullary vascular bundles with inverse orientation of the wood and bast are formed ; these bundles must be distinguished from the medullary vascular bundles of *Campsis radicans*, &c. (see § 56).

Intraxylary phloem is found in the following Orders, being constantly present as a rule in those indicated by a * : *Vochysiaceae (excl. Trigoniaceae), *Combretaceae (excl. *Macropteranthes* and the Gyrocarpeae), *Myrtaceae sens. str., *Melastomaceae, *Lythrarieae (incl. *Punica* and *Olinia*), *Onagrarieae (incl. *Trapa*), *Cucurbitaceae (excl. the tribes Gynostemmeae, Zanonieae ? and Feuilleae ; the intraxylary phloem sometimes arising only at a late stage), *Apocynaceae, *Asclepiadeae, Loganiaceae

Paris, 1899, p. 167 ; Baranetzky, Faisc. bicoll., Ann. sc. nat., sér. 8, t. xii, 1900, pp. 261–322 and pl. vii–x ; Viret, Liaisons du phloème méd., periméd. et interligneux avec le liber normal, Travaux Inst. bot. Univ. Genève, sér. 6, Fasc. vi, 1904, 100 pp.

[1] The delimitation of what is known as 'intraxylary phloem' from the groups of medullary soft bast, discussed in the previous section, has not yet been quite finally accomplished, owing to the fact that the course of the intraxylary soft bast, in the various Orders in which it occurs, has not by any means been sufficiently investigated up to the present. In the case of some of the Thymelaeaceae Van Tieghem has shown that the groups of intraxylary soft bast do not pass out into the leaf. The necessity of investigating the course of these strands of phloem is shown by the cases (*Campanula pyramidalis* and *Lactuca perennis*), mentioned by J. E. Weiss ; here one finds medullary phloem-bundles, which, as shown by their course, correspond in part to intraxylary phloem and in part to the ordinary medullary phloem-bundles of the Campanulaceae and Cichoriaceae (see above). In the subsequent list of Orders having intraxylary phloem these two cases are not further considered for the sake of convenience.

(*Loganioideae), *Gentianeae (excl. Menyantheae, for the apparent exception '*Leiphaimos*,' see p. 994), *Convolvulaceae (incl. Nolaneae and excl. *Humbertia* and the Cuscuteae), *Solanaceae (excl. *Retzia*), Acanthaceae (*Barlerieae, *Nelsonia*), Myoporineae (*Oftia*), *Basellaceae (correctly included here ?, intraxylary phloem namely developing at a late stage), Polygonaceae (*Emex*, etc., really intraxylary phloem ?), *Thymelaeaceae (excl. *Drapetes*), *Penaeaceae, Euphorbiaceae (*Eucrotoneae excl. species of *Croton* of the section *Astraea* ; *Alchornea*, *Conceveiba*, *Lepidoturus*, *Pera*, *Mallotus* pro parte ; *Dactylostemon*, *Mabea*, *Senefeldera*, *Sebastiania* pro parte).

The great systematic value of the intraxylary phloem is sufficiently evident from the preceding table. Thus, it often constitutes an ordinal character ; it is frequently found in groups of allied Orders ; the Scrophularineae and Solanaceae are sharply distinguished by the absence and presence respectively of intraxylary phloem, &c.

We may add here that **intraxylary phloem** only rarely occurs **in the root** (in certain species of *Oenothera*, *Vinca*, *Strychnos* and *Chironia*, and in those Cucurbitaceae, which have a pith). In most cases we find the internal phloem passing to the outside (simultaneously with the primary vessels) already in the region of the hypocotyl, the intraxylary phloem then entering into connexion with the outer phloem of the root. In other cases the intraxylary phloem is continued into the root as interxylary phloem (e.g. in species of *Oenothera*, cf. § 58, p. 1162)

§ 58. INTERXYLARY PHLOEM [1]. The term 'interxylary phloem' is used to denote groups of soft bast, which are enclosed in the wood of the vascular ring. In the previous summary (see 'Systematische Anatomie,' German Edition, 1899, pp. 972 et seq.) we followed the example of H. Schenck in distinguishing three types, but in view of Leisering's researches these are better comprised in the following two types. In the **first type**, which may retain the earlier name of '*Strychnos*-type,' the groups of interxylary soft bast are given off by the cambium on its outer side in a perfectly normal manner, as is generally the case with the soft bast ; subsequently, however, these groups of phloem become bridged over by a cambial arc, which develops in the pericycle on their outer side ; as a result of the activity of this cambial arc, which produces wood internally and bast externally in the ordinary way, the groups of interxylary phloem become sunk in the xylem-mass. A **modification of this type** is found in the cases mentioned below as occurring in certain Acanthaceae, Apocynaceae and Bignoniaceae ; here the groups of soft bast (which play a part in the formation of the furrows (see § 61) in the xylem) are not embedded in the wood by the agency of new cambial arcs, but secondarily by the production of tissue formed from a proliferation of the strips of cambium, situated on either side of the furrows : a modification of the first type is likewise constituted by the anomaly, found in *Cuscuta japonica* (see p. 1004). In the **second type**, which includes both the other cases previously distinguished, the islands of interxylary soft bast arise by the subsequent differentiation of sieve-tubes in groups of thin-walled tissue, which are given off by the cambium on its inner side, together with the secondary wood. These groups of tissue are composed of cells, which at first have the character of unlignified elements of the wood-parenchyma. Their transformation into phloem may commence at a rather early stage, viz. immediately after they are produced by the cambium, in which case the groups of interxylary phloem may be said to be

[1] Solereder, Holzstr., 1885, p. 32 ; Hérail, in Ann. sc. nat., sér. 7, t. ii, 1885, p. 256 ; Scott and Brebner, in Ann. of bot., iii, 1889, p. 275 ; Van Tieghem, in Journ. de bot., 1891 ; Chodat, in Arch. sc. phys. et nat. Genève, 1892, p. 229, and Report of Congress, Genoa, 1893, p. 144 ; H. Schenck, Anat. d. Lianen, 1893, p. 17 ; Perrot, Tissu criblé, Thèse, Paris, 1899, p. 177 ; Leisering, Entwicklungsgeschichte des interxyl. Leptoms bei den Dicotyl., Diss., Berlin, 1899, 50 pp., 2 Tab., also in Bot. Centralbl., 1899, iv.

given off by the cambium on its inner side (i.e. the *Mucuna*-type previously distinguished), or it may be postponed until a relatively late stage (this being the case formerly distinguished as 'development of interxylary phloem by the subsequent differentiation of sieve-tubes in islands of unlignified tissue, which are situated in the xylem-mass'). These two cases are connected with one another by transitions, and it is only the extreme forms that can be properly distinguished from each other.

It may once more be emphasized that the two types of interxylary phloem above described are *perfectly different structures*. Practical considerations alone lead me to discuss them in the same paragraph and to class them together as interxylary phloem, since it is not always possible to determine their course of development in the material, which suffices for the mere demonstration of the anatomical features in question; moreover, the development of the interxylary phloem has not been investigated in all cases. Axes having interxylary phloem of the *Strychnos*-type are very closely related to the axes showing the anomaly discussed in § 59, in which successive annular or arc-shaped groups of wood and bast arise in the pericycle. The only essential difference between the two types of anomalies lies in the fact that in *Strychnos*, &c., the successive extinction and renewal of the cambium is confined to very small portions of the original cambial rings, while in the second case it affects the entire cambial ring or, at least, relatively extensive arcs of cambium. The *occurrence of transitional forms between the two kinds of anomalies* (see Hippocrateaceae) is in agreement with this close relationship.

Considered from the systematic point of view, the occurrence of interxylary phloem is mostly constant throughout all the species of a genus. It generally appears already in the first-formed mass of secondary wood, and is consequently developed in large quantity in the branches of herbarium-material. In other species, however, it arises only at a late stage and in such a case is not to be found in herbarium-material. It follows that if interxylary phloem can be demonstrated only in some of the species of a genus, when herbarium-material is being examined, it need not necessarily be absent in the remaining species. Judging by the experience gained in the investigation of the species of *Strychnos* (see p. 546), *it is far more probable that interxylary phloem occurs also in* those species, in which it is not developed in herbarium-material, but that it arises only in the later growth of secondary wood. Interxylary phloem is particularly widely distributed in genera belonging to Orders, which are distinguished by the possession of intraxylary phloem. The species provided with interxylary phloem may or may not be lianes. In those Orders, in which several genera have interxylary phloem, its mode of origin, as far as the hitherto published investigations show, is generally the same in all cases.

The islands of interxylary soft bast vary in size, sometimes (e.g. in many Barlerieae) even being very small; in a transverse section they are (mostly) rounded or (more rarely) elongated in the form of tangential bands and are commonly arranged in concentric rings. The groups of interxylary soft bast, found in *Condylocarpon* (Apocynaceae, Fig. 123, p. 533) and certain Bignoniaceae, are peculiar in being elongated in the radial direction; the development of phloem-islands in these cases is connected with the formation of furrows in the wood (see above, and pp. 533 and 605). Bast-fibres are rarely (Aquilarieae) found in the groups of interxylary phloem.

Interxylary phloem occurs not only in the stem, but also in the root. The development of the interxylary phloem in the latter conforms to the same two types, as have been distinguished in the stem. In some cases the islands of soft bast found in the wood of the root appear as downward prolongations of the strands of intraxylary phloem occurring in the stem (cf. § 57, p. 1161).

Interxylary phloem has been found in the stem or root, or in both, in the follow-

ing Orders and genera respectively[1]: Vochysiaceae (*Erisma*, subseq. diff.); Hypericineae (*Endodesmia*); Malpighiaceae (*Dicella* and *Stigmaphyllon*, subseq. diff.); Olacineae (*Sarcostigma*, Str.-type; *Chlamydocarya*): Hippocrateaceae (*Salacia*, Str.-type, Fig. 51, p. 217); Papilionaceae (*Dioclea*, *Mucuna* and *Phaseolus*, subseq. diff.); Mimoseae (*Entada*, subseq. diff.); Combretaceae (*Calycopteris*, *Combretum* and *Guiera*, Str.-type; *Thiloa*); Melastomaceae (*Memecylon*, *Mouriria*, *Kibessia*, *Pternandra*, Str.-type; wood of the root of *Memecylon*); Lythrarieae (wood of the root of *Lythrum*, subseq. diff.); Onagrarieae (wood of the stem and root of *Oenothera* and *Epilobium*, and wood of the root of *Gaura* and *Lopezia*, probably always subseq. diff.); Cucurbitaceae (wood of the root of *Cucurbita* and *Thladiantha*, subseq. diff., in part as a continuation of the intraxylary phloem of the stem); Candolleaceae[?] (*Candollea*, really interxylary phloem ?, see p. 963 and § 56 under 'cortical bundles'); Plumbagineae (in the anomalous growth of the wood of *Aegialitis*, cf. § 50); Salvadoraceae (*Salvadora*, subseq. diff.: *Dobera*, *Platymitium*; wood of the root of *Salvadora*); Apocynaceae (*Condylocarpon*, in connexion with the formation of furrows in the wood; *Lyonsia*, subseq. diff.): Asclepiadeae ('*Ceropegia macrocarpa*,' subseq. diff.; lower part of the stem and root of *Asclepias obtusifolia*, Michx., subseq. diff., in the root also as a continuation of the intraxylary phloem of the stem; wood of the root of *Asclepias syriaca*, subseq. diff.: wood of the root of *Morrenia brachystephana*); Loganiaceae (*Strychnos*, Str.-type; *Antonia*, *Norrisia*, *Bonyunia*, *Logania*); Gentianeae (*Chironia*, *Crawfurdia*, *Ixanthus* and *Orphium*; wood of the root of very many Gentianoideae, see p. 995, probably in all cases subseq. diff.); Convolvulaceae (hypocotyl of *Ipomoea versicolor*, subseq. diff.); Cuscuteae (*Cuscuta japonica*, see p. 1004); Solanaceae (wood of the root of *Atropa*, *Datura* and *Scopolia*, subseq. diff.; wood of the root of *Browallia*); Bignoniaceae (embedded bast-wedges in *Distictis*, *Haplolophium*? and *Pithecoctenium*): Acanthaceae (Barlerieae, in *Barleria* subseq. diff.; *Thunbergia*, subseq. diff., Fig. 147, p. 622, sometimes developing from wedges of soft bast); Thymelaeaceae (*Aquilaria*, *Gyrinops*, *Gyrinopsis* and *Linostoma*, subseq. diff.; *Brachythalamus*, *Lophostoma*, *Synaptolepis*); Loranthaceae (*Nuytsia*, Str.-type); Euphorbiaceae (*Dalechampia*, subseq. diff.).

In connexion with the groups of interxylary soft bast of the second type (i. e. those arising secondarily from groups of unlignified wood-parenchyma), we may notice the occurrence of **interxylary vascular bundles**, showing concentric structure with central phloem, in the rhizome of *Cochlearia Armoracia* and in the roots of certain other Cruciferae (J. E. Weiss). These bundles take their origin from groups of phloem, which develop secondarily in the wood-parenchyma and subsequently become enveloped by a ring of cambium, which gives off wood on its outer side.

§ 59. Successive Development of Secondary Groups of Wood and Bast[2]. The development of successive secondary groups of wood and bast has been observed both in lianes and in non-lianes and is either characteristic of species only or serves to distinguish genera or even Orders. The diverse appearance presented by the axes, which show this anomaly, depends on the time at which the latter appears, as well as on the place of origin, the shape and the mode of differentiation of the secondary groups of wood and bast. The formation of the secondary groups sometimes takes place at a very early period, while in other cases they only arise at a very late stage; it is only in the former case that the anomaly can be demonstrated in herbarium-material. The secondary groups of wood and bast either form (*a*) complete rings (successive zones of growth), which are arranged concentrically with reference to the ring of primary vascular bundles, or (*b*) segments of such rings, or (*c*) mere strands, which occasionally project towards the exterior in the form of weals or ribs.

[1] Unless there is a statement to the contrary, these data refer to the occurrence of interxylary phloem in the stem; the abbreviations 'Str.-type' (i.e. *Strychnos*-type) and 'subseq. diff.' (i.e. subsequent differentiation—at an earlier or later stage—of phloem from groups of thin-walled tissue, given off by the cambium on its inner side) are used to indicate the two chief types. For details as to course of development, see the descriptions of the individual Orders.

[2] See especially H. Schenck's 'Anatomie der Lianen' (1893), on which the description of the anomalously constructed axes in the special part of this book is altogether mainly based.

In addition to that, the secondary rings of wood and bast or segments of wood and bast, as in the case of the primary vascular ring, either form closed zones traversed only by narrow medullary rays, or are split up into so-called secondary vascular bundles by broad plate-like medullary rays, which may or may not be lignified. I shall return below to certain special cases presented by this anomaly. The place of origin of the secondary groups of wood and bast varies. The secondary meristems, from which they arise, originate either in the inner cell-layers of the primary cortex (occasionally in the innermost (endodermal) layer of the latter) or in the parenchymatous pericycle, or in the phloem of the original vascular ring. As a matter of practical convenience the last two modes of development are not kept distinct in the following enumeration of Orders and genera, which show this anomaly, since it is often enough (and especially in the case of herbarium-material) difficult to determine, whether the secondary structures develop from the pericycle or from the outermost cell-layers of the soft bast. Nor is it always easy to settle, whether the pericycle or the inner layers of the primary cortex are the seat of the anomalous growth, this being the case when pericyclic sclerenchyma or a distinctly differentiated endodermis are absent.

The point of origin of the secondary structures is generally constant throughout all the species of a genus, but this is not always the case (see *Forchhammeria* and *Spatholobus*); in the same Order it may vary from genus to genus, or may be identical in all the species showing anomalous structure.

The **development of secondary groups of wood and bast** from meristems, which arise in a distinct extrafascicular position **in the primary cortex**, has been observed in the following Orders and genera respectively[1]: Menispermaceae (*Abuta*, *Anomospermum*, Fig. 8, p. 43, *Chondrodendron*, *Cocculus*, *Pachygone*, *Pericampylus*; also in the root of *Abuta*, *Chondrodendron*, *Cocculus*, *Cissampelos* and *Clypea*); Capparideae (*Cadaba*, *Forchhammeria*); Caryophylleae (in the root or also in the stem of *Spergularia* and *Polycarpaea*, Fig. 25, p. 108; here we may probably include also the anomaly found in the root of *Cerdia*, *Ortegia*, *Polycarpon*, *Pycnophyllum*, *Silene*[2], *Spergula* and *Stipulicida*); Papilionaceae (*Derris*, *Rhynchosia*, *Spatholobus*, *Wistaria*); Cucurbitaceae (*Actinostemma*, *Momordica*); Umbelliferae (*Eryngium*); Compositae (*Coreopsis*); Plumbagineae (*Aegialitis*, see § 58, p. 1163); Verbenaceae (*Avicennia*).

The **development of secondary groups of wood and bast** from meristems, which arise **in the parenchymatous pericycle** or (more rarely) **in the bast of the original vascular ring**, has been observed in the following Orders and genera respectively: Dilleniaceae (*Doliocarpus*); Capparideae (*Forchhammeria*, *Maerua*, *Roydsia*); Polygaleae (*Bredemeyera*, *Comesperma*, *Moutabea*, *Securidaca*, Fig. 23, p. 99); Olacineae (*Phytocrene* with successive rings, consisting of plates of wood and bast, Fig. 49, p. 208; *Trematosperma*, undetermined member of the tribe Icacineae); Hippocrateaceae (*Salacia* with transitions to interxylary phloem, see § 58, and Fig. 51, p. 217); Rhamneae ? (*Gouania* ?); Ampelidaceae (*Tetrastigma*); Sapindaceae (corded xylem-mass in *Paullinia*, *Serjania* and *Thinouia*, Fig. 53, p. 235); Papilionaceae (*Derris*[3], *Machaerium*, *Mucuna*, *Pachyrhizus*, *Pueraria*, *Spatholobus*, *Strongylodon*); Caesalpinieae (*Bauhinia*); Cucurbitaceae (only in the root of *Ecballium elaterium*); Ficoideae (as far as is known, in all the woody genera except *Polpoda*, also in the root); Rubiaceae (*Chiococca*); Compositae (*Mikania*, *Kleinia*, *Dahlia*); Candolleaceae ? (*Candollea*, really belonging to this category ?); Plumbagineae (*Acantholimon*); Convolvulaceae (*Argyreia*, *Calonyction*, *Hewittia* ?, *Ipomoea*, *Maripa*, *Merremia*, *Porana*, Fig. 130, p. 571, *Rivea*); Bignoniaceae (*Callichlamys*, *Distictis*, *Doxantha*, *Glaziovia*, *Haplolophium*); Labiatae (*Thymus*); Nyctagineae (quite generally in the woody species, Fig. 155, p. 648;

[1] The above data as a rule refer to the stem, except when there is a statement to the contrary; in those species, in which the anomaly occurs in the stem, it is, however, very frequently found also in the root (for details on this point, see the diagnoses of the individual Orders, and Schenck, loc. cit., pp. 251-6).

[2] In *Silene acaulis*, L. according to my own investigation.

[3] *Derris* is included also at this point on the authority of H. Schenck (loc. cit., p. 176), who mentions the 'secondary cortex' as the seat of the formation of the anomalous growth.

also in the root); Illecebraceae (*Pollichia*; here we may probably include the anomaly found in the stem of *Cometes* and *Corrigiola*, and in the root of *Acanthonychia*, *Achyronychia*, *Cometes*, *Corrigiola*, *Dysphania*, *Haya*, and *Pollichia*); Amarantaceae (of almost general occurrence in the woody species, Fig. 157, p. 654, also in the root; wanting in *Achatocarpus* and *Cladothrix*); Chenopodiaceae (quite generally in the woody species, also in the root); Phytolaccaceae (*Agdestis*, *Ercilla*, *Gallesia*, *Phytolacca*, *Seguieria*, in *Agdestis* and *Phytolacca* also in the root; here we may probably also include the anomaly found in the stem of *Barbeuia*, *Petiveria* and *Rivina*, and in the root of *Anisomeria*); Polygonaceae (*Antigonon*); Loranthaceae (*Loranthus*; *Nuytsia*, see § 58); Euphorbiaceae (*Dalechampia* and *Fragariopsis*, secondary strands of wood and bast, appearing like ribs); Buxaceae (*Simmondsia*, also in the root).

The place of origin of the secondary groups of wood and bast in the axis still remains to be determined in *Dalbergia* (Papilionaceae), *Erycibe* (Convolvulaceae, here developed in connexion with a cleavage of the xylem-mass), and in some of the genera of the Caryophylleae, Illecebraceae and Phytolaccaceae already enumerated under their respective Orders in the two previous paragraphs.

We may lastly add, that according to Maheu, the anomalous growth in the Menispermaceae shows a varied mode of development, and is found also in *Chasmanthera*, '*Menispermum*,' and *Stephania* (see p. 818); Maheu's statements, however, still require to be verified.

The **structure of the anomalous growth deserves special mention** in the case of the Sapindaceae, *Chiococca*, *Aegialitis*, *Phytocrene*, and in certain Ficoideae, Nyctagineae, Amarantaceae and Chenopodiaceae. The secondary masses of wood and bast, which give rise to the corded xylem-mass of the Sapindaceae (Fig. 53, p. 235), are always annular and completely enveloped by cambium, but apart from that they are either cylindrical or flattened. They are related to the strands of wood and bast, which are found in *Chiococca* (Fig. 102, p. 453) and which are likewise provided with a ring of cambium. *Aegialitis* is distinguished by the fact that only one secondary meristem is formed; this produces a ring of wood including large groups of interxylary soft bast on its inner side, but there is no formation of bast on the outer side. The successive rings of growth found in *Phytocrene* are peculiar, owing to the fact that they consist of groups of wood and plates of bast, which alternate with one another in the tangential direction (see Fig. 49, p. 208). In many Ficoideae, Nyctagineae (Fig. 155, p. 648), Amarantaceae (Fig. 157, p. 654), and Chenopodiaceae, lastly, the secondary bundles of wood and bast are enveloped by prosenchymatous interfascicular tissue, which is likewise formed by the secondary meristems; this tissue is sometimes traversed by medullary rays or may include vessels. In the Nyctagineae, Amarantaceae, and Chenopodiaceae, the ground tissue situated between the primary vascular bundles and the tissue formed at the commencement of the activity of the secondary meristem, is occasionally differentiated like a pith, and in such cases the primary vascular bundles appear as apparent medullary bundles (see § 56).

As regards the composition of the secondary strands of wood and bast we may add that primary tracheae with spiral and annular thickenings, such as occur quite generally in the leaf-trace bundles, are almost invariably wanting in the secondary strands.

§ 60. Compound and Divided Xylem-masses [1]. Both types of anomalies depend on a special arrangement of the vascular bundles at the time of their development. In the case of the compound xylem-mass, which occurs in certain species of *Serjania* (Fig. 53, p. 235) and *Paullinia*, and in an undetermined member of the Leguminosae (Fig. 62, p. 281), one finds in addition to a central ring of vascular bundles a number of peripheral rings of wood and bast; each of the latter includes a pith, is provided with primary spiral tracheae and grows in thickness by means of a ring of cambium. The divided xylem-mass

[1] Cf. Radlkofer's papers cited on p. 236, and H. Schenck, Anat. d. Lianen, 1893, p. 81 et seq.

(Fig. 53, p. 235) lacks the central ring of vascular bundles found in the case of the compound xylem-mass. It takes its origin from a ring of horseshoe-shaped groups of vascular bundles, each of these groups being open on its inner side and having a pith, which in early stages still communicates with the central pith; subsequently, however, the rings become closed. A divided xylem-mass is found only in *Serjania corrugata*, Radlk., and a few allied species. For details, see p. 234.

§ 61. Unequal Thickening of the Xylem-mass[1]. Among the axes showing anomalous growth it is usual to include a number of structures, which appear in certain lianes (provided with a normal ring of vascular bundles) in the course of secondary growth, and which are generally to be found only in axes of a certain degree of thickness (only rarely occurring in the branches of herbarium-material). These anomalies are due either to unequal growth in thickness of the wood alone or both of the wood and bast. In the former case, according to the manner in which the growth of the wood is accelerated, we obtain axes, which are flattened or band-shaped, or are provided with superficial furrows of varying breadth (ribbed or winged axes). In the case of strongly winged stems, as may be noticed in passing, the anomaly occasionally (*Sabicea*, *Lantana*) leads to an ultimate cleavage into longitudinal segments, corresponding to the wings. When both the wood and bast show irregular growth in thickness, the irregularity is not noticeable—or only faintly indicated—on the outer surface of the axis, owing to the fact that at those points at which the formation of the wood is retarded, there is a corresponding increase in the production of bast on the part of the cambium. In this way the xylem-mass, as seen in a transverse section, has a lobed outline, the furrows between the lobes being filled with phloem in the shape of bast-wedges. The ring of cambium in these cases is either continuous, so that it forms a complete lining to the furrows, or interrupted (Bignonieous type according to H. Schenck[1]), the cambial tissue being confined to the outer side of the projecting portions of the wood and to the base of the furrows (i.e. it is absent on the radial surfaces of the bast-wedges).

Flattened or band-shaped axes have been recorded in the following Orders and genera respectively: Papilionaceae (*Abrus*, *Machaerium*, *Rhynchosia*); Caesalpinieae (*Bauhinia*, Fig. 64, p. 290); Asclepiadeae (*Ceropegia*, *Ibatia*, etc.); Convolvulaceae (*Merremia*); Polygonaceae (*Coccoloba*); Ulmaceae (*Celtis*). **Ribbed or winged axes**[2], the outer surface of which is furrowed, have been observed in: Malpighiaceae (*Heteropteris*, Fig. 37, p. 166); Celastrineae (*Euonymus*, *Celastrus*); Sapindaceae (*Serjania*, *Urvillea*); Caesalpinieae (*Bauhinia*, Fig. 64, p. 290, *Cassia*); Mimoseae (*Acacia*, *Piptadenia*); Rubiaceae (*Sabicea*); Verbenaceae (*Lantana*); Polygonaceae (*Atraphaxis*, rightly included in this category ?). **Axes with bast-wedges**[3] are found in: Anonaceae (*Melodorum*); Malpighiaceae (*Heteropteris*, Fig. 37, p. 166, *Peixotoa*, *Tetrapteris*); Chailletiaceae (*Chailletia*); Phytocreneae (**Phytocrene*, **Pyrenacantha*); Hippocrateaceae (spec. indet.); Rubiaceae (*Lygodysodea*, *Manettia*, *Sabicea*); Compositae (**Bidens*, **Mikania*); Apocynaceae (*Allamanda*, *Alstonia*, *Condylocarpon*, Fig. 123, p. 533, *Echites*, *Lyonsia*, *Parsonsia*, *Tabernaemontana*); Asclepiadeae (*Gymnema*); Boragineae (*Tournefortia*); Convolvulaceae (*Merremia*); Bignoniaceae (numerous *Bignonieae with bast-wedges, which in transverse section are separated from the xylem-mass by lines, which are straight or resemble a staircase, *Pandorea*); Acanthaceae (*Afromendoncia*, *Mendoncia*, *Pseudocalyx*, *Thunbergia*).

In some of the cases, named in connexion with the last of these anomalies, the subsequent cleavage of the xylem-mass is initiated by the appearance of the bast-

[1] See H. Schenck, Anat. der Lianen, 1893, p. 15.

[2] The formation of furrows and wings in plants with reduced leaves (formation of 'micropteres' and 'macropteres' of Briquet) does not belong here and is therefore not considered at this point.

[3] The occurrence of bast-wedges of the Bignonieous type is indicated by a * in the following synopsis.

wedges (see § 62); in *Phytocrene* (see § 59), moreover, the development of successive zones of wood and bast having a characteristic structure, is combined with the anomaly in question; in a few cases (*Condylocarpon* and certain Bignonieae), finally, bast-wedges, which are formed successively in the radial direction, subsequently come to be enclosed in the xylem-mass (cf. § 58, p. 1162).

§ 62. Cleavage of the Xylem-mass [1]. Very complicated structures are produced by the cleavage of the xylem-mass of the stem. It commences with the splitting up of the ring of wood into a number of separate strands by a process of dilatation, i. e. cell-division in the parenchyma of the wood, the pith and the medullary rays. Subsequently meristems, which produce wood and bast, are frequently developed in connexion with these strands.

A **cleft xylem-mass** has been found in the following Orders and genera respectively: Caryophylleae (*Acanthophyllum*); Malpighiaceae (*Banisteria, Mascagnia, Mezia, Stigmaphyllon, Tetrapterys*, Fig. 37, p. 166); Sapindaceae (*Serjania, Urvillea*); Caęsalpinieae (*Bauhinia*, Fig. 64, p. 290); Umbelliferae (*Azorella*); Asclepiadeae (*Calotropis*); Convolvulaceae (*Erycibe, Merremia*); Bignoniaceae (*Bignonia*, Fig. 142, p. 606, *Doxantha, Dolichandra ?, Macfadyena, Melloa, Parabignonia ?*); Acanthaceae (*Afromendoncia, Mendoncia, Pseudocalyx ?, Thunbergia*); Aristolochiaceae (*Aristolochia*, Fig. 167, p. 686).

VII. Structure of the Root.

§ 63. General Structure of the Root [2]. The structure of the root in the Orders of Dicotyledons has not yet been methodically investigated to any considerable extent, because the requisite material is generally wanting, and the anatomical investigation of the leaf and axis, which are more easily obtained and show a greater diversity of structural features, still affords abundant scope for research. The more important characters, to be taken into account in an investigation of the root, are as follows: (*a*) the number of xylem- and phloem-groups in the primary fibrovascular system (exceptionally very large,—as in the case of Monocotyledons,—in *Lophira*, or reduced to a monarch condition in the delicate lateral roots of *Trapa*), a feature which is occasionally of considerable systematic value (e. g. diarch roots in the Gentianeae-Gentianoideae, 5–9-arch roots in the Menyanthoideae), although sometimes varying within certain limits in one and the same species; (*b*) the mode of differentiation of the secondary xylem-mass, the ground-mass of the wood being either (1) unlignified and in this case containing vessels only or vessels together with scattered groups of wood-fibres, or (2) lignified, in which case it is composed for the most part of wood-fibres; these features are connected with the physiological functions of the root (as a nutritive or attaching organ, as a respiratory root, &c.), and are therefore subject to variation within certain limits in one and the same species; (*c*) the rare occurrence of hard bast in the phloem-groups (Anonaceae, Malvaceae, Sterculiaceae, Tiliaceae, Papilionaceae, Urticaceae); (*d*) the structure of the endodermis, including among other features the occurrence of secondary division-walls in this layer (Valerianeae, Compositae, Gentianeae-Gentianoideae); (*e*) the structure of the hypodermal

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[1] See H. Schenck, loc. cit., 1893, p. 22, and in Pringsheim Jahrb., xxvii, 1895, p. 581.

[2] Van Tieghem, Traité de bot., 1891, p. 673, and Van Tieghem et Douliot, in Ann. sc. nat., sér. 7, t. viii, 1888; Krämer, Wurzelhaut, Hypodermis u. Endodermis der Angiospermenwurzel, Bibl. bot., Heft 59, 1903, also Diss., Marburg, 151 pp. and 6 Tab.; Freidenfeldt, Anat. Bau d. Wurzel, Bibl. bot., Heft 61, 1904, 118 pp. and 5 Tab. (see also in Botaniska Notiser, 1900, Heft 5, and Flora, 1902, p. 115 et seq.); Leavitt, Trichomes of the root, Proceed. Boston Soc. Nat. Hist., xxxi, 1904, pp. 273–313; Neuber, Vergl. Anat. d. Wurzeln mit bes. Berücksichtigung der Heterorhizie bei Dicotyl., Diss., Bern, 1904, 70 pp.; Tschirch, Heterorhizie, Flora, 1905, pp. 68–78; Büsgen. Wurzelsysteme einiger dicotyler Holzpflanzen, Flora, 1905, Ergänz.-Band, pp. 58–94 and Tab. i–iv, especially p. 91.

cell-layers, which are frequently marked off from the remaining ground-tissue; (*f*) the occurrence of peculiar ridge-like or otherwise-shaped thickenings (Van Tieghem's 'réseau de soutien') in the subepidermal layer of cells or in more deeply situated cells of the primary cortex (especially in the layer of cells external to the endodermis); (*g*) the structure of the root-hairs (branched in *Brassica, Saxifraga*, &c., in other cases grouped together in tufts, in the Nymphaeaceae originating from idioblasts in the dermatogen); (*h*) the presence of secretory organs, their position with reference to the primary fibrovascular system of the root in some cases being of importance in the diagnosis of an Order, e. g. the dorsal position of the resin-canals with regard to the primary phloem-groups in the Pittosporeae, Araliaceae and Umbelliferae, which is connected with a doubling of the usual number of young lateral roots, the endodermal origin of the resin-canals in the Compositae, &c. (cf. § 13 et seq.); lastly, (*i*) the occurrence of mycorrhiza[1].

A strengthening net-work ('**réseau de soutien**')[2] has been observed in the following Orders: Berberideae, Cruciferae (Fig. 17, p. 66), Geraniaceae (Fig. 39, p. 170), Rutaceae, Sapindaceae, Papilionaceae, Caesalpinieae, Rosaceae, Rhizophoraceae, Lythrarieae ?, Caprifoliaceae, Ericaceae, Myrsineae, Verbenaceae. In the plants, which form the landscape of the mangrove, the ridge-like thickenings are found only in some parts of the root-system, which is here adapted to carry out diverse functions. Regarding similar thickenings in *Acanthus ilicifolius*, which likewise grows in the mangrove-formation, see under Acanthaceae, p. 1020.

§ 64. Anomalous Structure of the Root. The occurrence of intraxylary and interxylary phloem and of successive secondary zones of wood and bast in the root has already been dealt with in §§ 57, 58 and 59 in connexion with the analogous features found in the stem[3]. In this paragraph a few other cases of anomalous root-structure may be briefly mentioned, viz.: (*a*) the development of concentric vascular bundles with central phloem in the wood of the root in species of *Brassica* and *Raphanus*; (*b*) the formation of concentric vascular bundles with central xylem or rarely (*Drosera*) phloem in the wood of the root, which frequently leads to a separation of the fibrovascular system into concentric vascular bundles, arranged in one or more rings (in certain Crassulaceae, species of *Drosera*, Cucurbitaceae, Umbelliferae, Fig. 97, p. 425, Compositae and Convolvulaceae, Fig. 131, p. 572); (*c*) the occurrence of similar structures, which, however, show a different course of development, in species of *Aconitum* (Ranunculaceae); (*d*) the complicated structure of the roots of *Myrrhis* (Umbelliferae), *Atractylis* (Compositae) and certain Convolvulaceae, which is produced by the appearance of secondary meristems in the wood or sometimes (Convolvulaceae) in the secondary bast and the formation of secondary groups or rings (the latter occasionally being inversely orientated in the three Orders named) of wood and bast; (*e*) the occurrence of cortical vascular bundles in the tuberous roots of *Myrmecodia* (Rubiaceae). For details, particularly as regards the course of development of these anomalous structures, see the descriptions of the individual Orders.

For a process of **cleavage, which sets in in roots and rhizomes** in the course of growth in thickness (Ranunculaceae, Fumariaceae, Crassulaceae, Gentianeae, Labiatae; also Plantagineae, according to Pilger), see especially Jost, in Bot. Zeit., 1890, p. 433 et seq. and Tab. vi; the cleavage in these cases is due to the removal of groups of dying tissue, while the intervening living tissue continues its growth.

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[1] In the root internal development of the cork is of general occurrence, the outermost cell-layer of the pericambium giving rise to the first phellogen.

[2] Van Tieghem, in Ann. sc. nat., sér. 7, t. vii, 1888, p. 375.

[3] See H. Schenck, Anat. der Lianen, 1893, pp. 251–6.

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GLOSSARY

[The main object of this glossary is to give a synopsis of the chief terms used in anatomical description (including a considerable number used in this work for the first time) together with their German equivalents. A few definitions are supplied, but more generally a reference is given to a page in the *Concluding Remarks* or in the main portion of the book, on which the term in question will be found to be more or less fully explained. The glossary may also serve as a rough index to the *Concluding Remarks*, and, with this object in view, rather more terms have been included than would have been necessary solely for the purposes of the glossary. In a few cases, where the English and German terms are practically identical, the latter have been omitted.

F. E. FRITSCH.]

A

Abietiform hairs (*i.e.* hairs branched like a fir-tree), Tannenbaumhaare (p. 1122).

Acarodomatia (p. 1132).

Acicular crystals, Kristallnädelchen, nadelförmige Kristalle (pp. 1104, 1106); *acicular fibres* (*raphidines*), Nadelfasern (p. 1155).

Active cells (of the pith), Aktive Zellen (p. 1133).

Adjacent cells (of stomata), Nachbarzellen (see *neighbouring cells*).

Aërenchyma, Aërenchym (p. 1150).

Air-canal, *air-passage*, Luftgang; *air-pores* (= stomata), Luftspalten.

Alumina-bodies, Tonerdekörper (p. 1109).

Ampulliform (depressions, &c., i. e. such as are shaped like a flask), krugförmig.

Anchor-hairs (cf. p. 379), Ankerhaare (p. 1117); *anchor-like shaggy hairs*, Ankerzotten.

Annual rings (in the wood), Jahresringe (pp. 1136, 1137).

Annular, ringförmig, ringartig; *annular tracheides* (i. e. provided with annular thickenings), Ringtracheiden.

Anthocyanin, Anthocyan (p. 1074).

Antler-like, *antler-shaped* (generally applied to trichomes), hirschgeweihartig, geweihartig.

Apical pores (of water-plants), Apikalöffnungen (see p. 1086).

Apiculus, Spitzchen.

Apparent medullary bundles, scheinbar markständige Gefässbündel (p. 1165).

Appendicular ridges (of stomata), Anhangsleisten (see *horns*) (p. 1082).

Aqueous tissue, Wassergewebe (see pp. 1077, 1087).

Arcs (of fibres, &c.), Bogen; *arc-shaped*, *arched*, bogenförmig; *arched outwards*, vorgewölbt.

Arm-palisade-cells, Armpallisadenzellen (see p. 1087); *arm-portion* (of two-armed hairs), Armteil.

Articulated, abgegliedert, gegliedert; *articulated hairs* (cf. p. 251), Gliederhaare.

Ascidia, *ascidiform leaves*, Schlauchblätter.

Astelay, Astelie (p. 1157, footnote).

Attenuated (i. e. gradually drawn out into a point, applied to hairs), sich verjüngend, auslaufend, verjungt.

Auricles, Öhrchen; *auriculiform* (i.e. ear-shaped), öhrchenartig.

Axial wood, Axiales Holz (p. 1145).

B

Back-cavity (of stomata), Hinterhof (p. 1081).

Band-shaped (*flattened*) *axes*, bandförmige (abgeflachte) Axen (p. 1166).

Barbed hairs (cf. p. 379), Widerhakenhaare; *barbs*, Widerhaken.

Bark, Borke (p. 1147).

Barrel-shaped, tonnenförmig.

Bars (the persistent portions in a scalariform perforation), *Speichen*.

Base (*foot*) *of hair*, Haarfuss (pp. 1091, 1124); *base of shaggy hair*, Zottenfuss.

Basin, Napf (applied to part of the complicated secretory cells of Magnoliaceae, Canellaceae, &c., see p. 1096); *basin-shaped*, schalenförmig, schüsselförmig.

Bast-fibres, Bastfasern (p. 1152); *bast-groups*, Bastteile (p. 1154); *bast-wedges*, Bastkeile (p. 1166).

Bays (of undulated walls), Buchten.

Beam-like, balkenartig; *transverse beams*, Querbalken; *beams of cellulose*, Zellstoffbalken.

Bellows-like, blasebalgartig.

Bicollateral bundles (p. 1160).

Bifacial (structure of leaf), bifacial, bifazial (see p. 1086).

Bilobed, zweiknopfig, zweilappig.

Bladder-hairs, Blasenhaare (p. 1116); *bladder-like*, blasig; *raised like a bladder*, blasig abgehoben; *swollen like bladders*, blasig aufgetrieben.

Botryoidal (i. e. shaped like a bunch of grapes), traubig.

Bracket-cells, Klammerzellen (p. 1100); *Bracket-epithelium*, Klammerepithel (p. 1100); *Bracket-hairs*, Klammerhaare (pp. 1117, 1119); *bracket-shaped*, klammerartig.

Brick-like, backsteinartig.
Bristle, Borste; *bristle-hairs*, Borstenhaare; *bristle-like*, borstig, borstenförmig.
Brush-shaped, pinselförmig; *brush-like shaggy hairs*, Pinselzotten.
Bulbous hairs, Zwiebelhaare (p. 1129); *bulbous and swollen*, zwiebelig angeschwollen.

C

Calcification, Verkalkung (p. 1111); *calcified*, verkalkt.
Callosity, Schwiele.
Cambiform strands (pp. 1158, 1159), Cambiformbündel.
Candelabra-hairs, Kandelaberhaare (pp. 1115, 1119, 1122); *candelabra-hairs of the shaggy type*, Kandelaberzotten (p. 1122).
Caoutchouc bodies, Kautschukkörper (p. 1109).
Capitate, kopfig, kopfförmig, köpfchenartig; *capitate hairs* (i.e. hairs ending in a swollen head), Köpfchenhaare (see p. 1119 and under *glandular hairs*).
Caps of cellulose, Cellulosekappen.
Cartilaginous, knorpelig.
Cauline (bundles, i.e. bundles belonging to the stem only), stammeigen.
Cell-fusions, Zellfusionen.
Cellular prominences, Zellhöcker, Zellhügel.
Cellulose, Zellstoff; *Cellulose-caps*, see under *caps*; *strands* (*beams*) *of cellulose*, Zellstoffbalken.
Centric (leaf-structure), centrisch (see pp. 1083, 1086).
Chalk-glands, Kalkdrüsen (see pp. 1086, 1128, 1133).
Chambered, gekammert; *one-*, *two-*, *many-chambered*, ein-, zwei-, vielkammerig; *chambered fibres* (*chambered crystal fibres*), Kammerfasern (Krystallkammerfasern) (p. 1154); *chambered crystal-parenchyma* (chambered parenchyma containing crystals), Krystallkammerparenchym (pp. 1108, 1143).
Characteristic region (of the petiole), 'caractéristique' (p. 1094).
Chimney (applied to stomata), Kamin (p. 1085).
Clavate, see *club-shaped*.
Cleavage (of xylem-mass), Zerklüftung, Spaltung (pp. 1166, 1167, 1168).
Cleft xylem-mass, zerklüfteter Holzkörper (p. 1167).
Climbing hairs, Klimmhaare (p. 1117).
Closed (applied to pericyclic strengthening ring and vascular ring), geschlossen (p. 1152); *closing membrane* (of stomata), Schliesshaut.
Clothing hair, Deckhaar (p. 1115 et seq.; of a papillose or vesicular type, p. 1116); *clothing membrane* (of intercellular spaces), Hautauskleidung; *clothing shaggy hairs*, Deckzotten (p. 1123).
Club-shaped, *clavate*, keulenförmig.
Clusters, Drusenkörper; *clustered crystals*, Drusen, Krystalldrusen (pp. 1104, 1105); *hairs containing clustered crystals* (cf. p. 740), Drusenhaare.
Collecting-cells, Sammelzellen (see p. 1087).
Collenchyma, Kollenchym (p. 1150).
Colleters (i.e. large hairs secreting mucilage and found on buds), Colleteren.

Columnar, säulenförmig, säulenartig; *columnar crystals* (i.e. *styloids*), Säulenkristalle (p. 1104).
Combined clothing and glandular hairs (p. 1125, footnote).
Commissures, Kommissuren; *commissural sieve-tubes* (cf. p. 396), Kommissuralsiebröhren; *commissural strands* (cf. p. 443), Strangverbindungen.
Compartments (of a palisade-cell, etc.), Fächer.
Complementary cells (of a lenticel), Füllzellen (p. 1149).
Component hairs (of tufted hairs, &c.), Teilhaare.
Composite (applied to pericyclic strengthening ring), gemischt (p. 1152); *composite* (*compound*) *xylem-mass*, zusammengesetzter Holzkörper (p. 1165).
Compound xylem-mass, see *composite xylem-mass*; *compound clothing hairs*, zusammengesetzte Deckhaare.
Concrescent, verwachsen.
Conical, kegelförmig.
Conjugate cells, conjugierte Zellen (see p. 1087).
Conjunctive tissue (i.e. that between and on the inner side of the vascular bundles of the stele), Zwischengewebe.
Connecting tissue (in the veins), Begleitgewebe (p. 1089).
Constriction, Einschnürung.
Containing-cells (of cystoliths), Trägerzellen (see *lithocysts*).
Contents (of a cell), Inhaltskörper.
Continuous (applied to pericyclic strengthening ring), kontinuierlich (p. 1152).
Contorted (applied to hairs, &c.), gewunden; *irregularly contorted*, kraus gebogen.
Contracted vascular systems, kontrahierte Leitbündelsysteme (p. 1155).
Corded xylem-mass, umstrickter Holzkörper (p. 1165).
Core (of a shaggy hair, &c.), Kern.
Cork, Kork (p. 1146); *cork-warts*, Korkwarzen (p. 1133).
Coronate (applied to papillae), mit Krönchen versehen.
Cortical vascular bundles, rindenständige Gefässbündel (p. 1159).
Cracks due to drying, Trockenrisse (p. 1088).
Crateriform, becherförmig; *crateriform glands*, Becherdrüsen (cf. p. 770).
Crenate (margin of shield of peltate hair), ausgerandet.
Crescent-shaped, sichelförmig.
Crests (on cuticle, guard-cells, &c.), Kämme (pp. 1072, 1085); *crest-like*, kammartig.
'*Cristarque*' (see p. 1090); '*cristarque*'*-cells*, Cristarque-Zellen (see pp. 1091 and 1151).
Crop-hairs, Kropfhaare (see pp. 557, 558); *crop-like*, kropfartig.
Cruciate, kreuzförmig.
Crypts (stomatal), Krypten (see p. 1084).
Crystal-cells, Kristallzellen; *crystal-conglomerates*, Kristallconglomerate; *crystal-hairs*, Kristallhaare (pp. 1107, 1118); *crystals of gypsum*, Gipskristalle (see p. 1076); *crystal-receptacles*, Kristallbehälter (p. 1107); *crystal-sacs*, Kristallschläuche; *crystal-sand*, Kristallsand (pp. 1104, 1106); *crystal-sclerenchyma*, Kristallsklerenchym (see pp. 1091–2, 1107).

Crystalline granules, Kristallkörnchen.
Crystalloids, Kristalloide (p. 1108).
Cucullate, kappenförmig.
Curly (applied to trichomes), kraus, krisp.
Curved (applied to lateral walls of epidermal cells in surface-view), gebogen (p. 1070).
Cuticular beads, Cuticularperlen; (*small cuticular crown* (of papillae), Cuticularkrönchen (see p. 1073); *cuticular crests*, Cuticularkämme (see p. 1072); *cuticular epithelium*, Cuticularepithel (p. 1149); *cuticular layers*, Cuticularschichten (p. 1072); *cuticular pegs*, Cuticularzapfen (p. 1072); *cuticular projections*, Cuticularvorsprünge; *cuticular ridges*, Cuticularleisten (p. 1072).
Cystoliths, Cystolithen (p. 1111); *cystolithic*, cystolithisch; *cystolith-like*, cystolithenähnlich; *cystolith-cells*, Cystolithenzellen; *cystolith-body*, Cystolithenkörper; *cystolith-formations*, Cystolithenbildungen; *cystolith-hair*, Cystolithenhaar, cystolithische Haare (p. 1111).
Cystospheres, Cystosphären (p. 1113).
Cystotyles (i.e. uncalcified cystoliths), pp. 1111, 1113).

D

Delimited, abgegrenzt.
Dendriform (applied to hairs), baumartig; *branched in a dendritic manner*, baumartig verzweigt.
Dendroid, baumartig; *Dendroid hairs*, Baumhaare, baumartig verästelte Haare (pp. 1118, 1119).
Denticulate (of perforations), gezähnelt.
Depressed, vertieft, eingesenkt; *depression* of guard-cells, &c.), Vertiefung, Einsenkung (p. 1085).
Dialystelic (p. 1156).
Digestive glands, Digestionsdrüsen (p. 1130).
Digitate, fingerförmig.
Dilatation (p. 1167).
Disc, Scheibe; *disc-shaped*, *discoid*, scheibenförmig; *discoid glands* (cf. p. 770), Scheibendrüsen.
Dissociation (of the vascular system), Zerspaltung, Auflösung (des Leitbündelsystems, p. 1155).
Distorted forms (of scalariform perforations), Krüppelformen (p. 1137).
Divided xylem-mass, geteilter Holzkörper (p. 1165); *division-walls*, Teilwände.
Dome-shaped, kuppenförmig.
Doubling, *duplication* (of epidermis, hairs), Verdoppelung; *double cystoliths* (*twin-cystoliths*), Doppelcystolithen (p. 1112).
Dumbbell-shaped, hantelförmig.

E

Ectocyclic sieve-tubes (cf. p. 396).
Eisodial ridges (i.e. on the outer surface of the guard-cells), Eisodialleisten.
Elevations of the cuticle, Kutikularerhebungen; *elevation* (of stomata), Emporhebung (p. 1084).
Emarginate, ausgebuchtet.
Embedded (of veins), eingebettet (p. 1089).
Empty cells (of pith), leere Zellen (p. 1133).
Encircled stomata (cf. p. 250), umkränzte Spaltöffnungen.
Endodermis, Schutzscheide, Phloeoterma (p. 1151).
Entocyclic sieve-tubes (cf. p. 396).
Epi-endodermal network (cf. p. 66), 'réseau sus-endodermique.'
Epithema, Epithem (p. 1086).
Excrescence, Wucherung.
Excretion of wax, Wachsausscheidung (p. 1072); *excretory receptacles*, Exkretbehälter (p. 1095).
External glands, Aussendrüsen (p. 1124); *external pore* (of stomata), Zuführungsspalt.
Extrafloral (*extranuptial*) *nectaries*, extranuptiale Nektarien (p. 1132).

F

Facets (of crystals), Flächen.
False pitting (of epidermal cells), Scheintüpfelung (p. 1072); *false scales* (cf. p. 380), Scheinschülferchen.
Fat bodies, *fatty bodies*, Fettkörper (p. 1109).
Felted hairs, Filzhaare; *felt-like*, filzig.
Few-barred (applied to scalariform perforations), armspangig, wenigspangig.
Fibre-like, *fibrous*, faserartig; *fibrous cells*, Faserzellen.
Filamentous, *filiform*, fadenförmig, fadenartig.
Fission, Zerklüftung (see *cleavage*); *fissured*, zerklüftet.
Fissures due to drying, Trockenrisse (see *cracks due to drying*).
Fistular (applied to the pith), röhrig.
Flagelliform (of hairs), peitschenförmig.
Flat-armed (applied to cells of the spongy tissue), flacharmig (p. 1087); *flatly arched*, flachgewölbt; *flattened axes*, see under *band-shaped*.
Flexile strength, Biegungsfestigkeit.
Fluke-cell (of anchor-hairs, cf. p. 271), Zinkenzelle.
Foot (of a hair), Haarfuss (p. 1124).
Foraminate perforations, Löcherperforationen (p. 1138).
Forked hairs (cf. p. 63), Gabelhaare; *forked shaggy hairs*, Gabelzotten (p. 1123); *forked glands*, Gabeldrüsen (p. 1128).
Friable, krumös.
Front cavity (of a stoma), Vorhof (p. 1081).
Funnel-cells, Trichterzellen (see p. 1087).
Furfuraceous (scurfy, applied to hairy covering), kleiig.
Furrows (in the xylem-mass), Furchen (p. 1166); *furrowed xylem-mass*, gefurchter Holzkörper (p. 1166); *furrowing* (of the xylem-mass), Furchung.
Fusiform, spindelig, spindelförmig.

G

Gamostelic (p. 1156).
Gelatinization, Verschleimung (pp. 1074, 1150); *gelatinized*, verschleimt.
Gelatinous layer (of wood-prosenchyma), Gallertschicht (pp. 1141, 1143); *gelatinous membrane* (of wood-prosenchyma), Gallertmembran.
Geniculate (of crystals, i.e. bent like a knee-joint), geknickt.
Girder-sclerenchyma, Trägersklerenchym; *I-shaped girders*, I-Träger; *girder-shaped*, trägerförmig.

Girdle (of subsidiary cells), Gürtel; *girdle-like, girdle-shaped*, gürtelförmig.
Gland, Drüse; *gland-like*, drüsenartig.
Glandular apparatus (*mechanism*), Drüsenapparat; — *disc*, Drüsenscheibe; — *epithelium*, Drüsenepithel; — *hairs*, Drüsenhaare (p. 1124); — *leaf-teeth*, drüsige Blattzähne (p. 1130); — *scales*, Drüsenschuppen; — *shaggy hairs*, Drüsenzotten (p. 1129); — *spots*, Drüsenflecke (p. 1131).
Gnarled (of spicular cells), knorrig.
Granular (applied to the cuticle), körnig (p. 1071); *granulated*, krumös (applied to crystals), gekörnt; *granulation* (of the cuticle), Körnelung.
Grooved xylem-mass, see *furrowed xylem-mass*.
Ground-mass, ground-work (of the wood), Grundmasse (p. 1141).
Gummosis (p. 1101).
Gum-resin, Gummiharz.
Gypsum-crystals, Gypskristalle (p. 1076); *gypsum-spheres*, Gypskugeln (cf. p. 72).

H

Hair, base (*foot*) *of*, see under B; *hair-cells*, Haarzellen; *hair-cystoliths*, Haarcystolithen (p. 1112); *hair-like*, haarartig; *hairy covering*, Behaarung (p. 1114 et seq.).
Heart-wood, Kernholz (p. 1136).
Helicoid (applied to shape of cystoliths), schneckenförmig.
Hemiconcentric bundles (of the petiole), 'Faisceaux hémiconcentriques' (Bouygues) (see p. 1094).
Hemitropic crystals, Hemitropieen.
Heterogeneous (applied to the pith), heterogen (p. 1134).
Hinge-cell (of hairs, &c.), Gelenkzelle.
Hippocrepiform (i.e. horseshoe-shaped), hufeisenförmig.
Homogeneous (structure of the leaf, see pp. 1083, 1086), homogen; *homogeneous* (pith, i. e. one consisting of empty or active cells only), homogen (p. 1134).
Hood-like, kapuzenförmig.
Hook, bent like a (applied to hairs, &c.), hakenförmig gekrümmt; *hooked hairs*, Hakenhaare (p. 1117); *hook-shaped*, hakenförmig.
Horizontal (applied to cells of medullary rays), liegend (p. 1144).
Horns (equivalent to outer appendicular ridges on guard-cells), Hörner, Hörnchen (p. 1082); *horn-bast* (i. e. groups of thickened and obliterated sieve-tubes), Hornbast; *horn, curved like a*, hornförmig gekrümmt.
Humps (projections on cell-walls), Buckeln; *hump, projecting like a*, buckelförmig vorspringend.
Hydathodes (i. e. special organs excreting liquid water), Hydathoden (p. 1076).
Hypoderm (p. 1076).
Hysterolysigenous, hysterolysigen.

I

Incrusting, krustig.
Incurved (outlines of cells), gebuchtet; *incurved* (tips of leaves), eingebogen.
Induplicate (margins of leaves), nach oben eingeschlagen.
Inequalities, irregularities (of the cuticle, &c.), Unebenheiten.
Infiltration (of silica, &c. in cell-walls), Einlagerung.
Infolded (margins of leaves), eingeschlagen.
Initial region (of petiole), Initiale (p. 1094).
Integumental glands, Hautdrüsen (p. 1128); *integumental* (*integumentary*) *tissue* (i. e. epidermis and hypoderm), Hautgewebe (p. 1074).
Interfoliar sides (see p. 207), Zwischenblattseiten.
Intermediate bundles, Zwischenbündel; — *fibres*, Ersatzfasern (p. 1135, footnote); — *tissue* (= conjunctive tissue), Zwischengewebe.
Internal glands, innere Drüsen, Innendrüsen (p. 1095 et seq.); *internal glandular hairs*, innere Drüsenhaare (p. 1096); *internal hairs* (*trichoblasts*), innere Haare (pp. 1091, 1092); *internal soft bast*, innerer Weichbast (p. 1159); *internal striation* (of epidermal walls), innere Streifung (p. 1072).
Interrupted (applied to ring of pericyclic sclerenchyma), unterbrochen (p. 1152).
Interwoven like felt (of hairs), filzig verflochten.
Interxylary phloem, holzständiges (interxyläres) Phloem (p. 1161); *interxylary vascular bundles*, holzständige Gefässbündel (p. 1163).
Intracambial (i. e. on the inner side of the cambium, see p. 113).
Intramedullary (bundles, cf. p. 587), intramedullare (Bündel).
Intramural glands (cf. pp. 254, 486), Zwischenwanddrüsen (p. 1100).
Intraxylary (i. e. on the inner side of the xylem) *phloem*, &c., intraxyläres Phloem (p. 1159), &c.
Inverse orientation, umgekehrte Orientierung.
Involuted (of glandular hairs), eingerollt.
Irregularities, see *inequalities*.
Islands of soft bast (applied to interxylary phloem), Weichbastinseln (p. 1161).

J

Jagged crown, small (at the end of a leaf-papilla), zackiges Krönchen; *jagged prominences*, Zacken; *jagged margins* (of epidermal cells, shields of peltate hairs), gezackte Ränder.
Joint (of hairs), Gelenk; *joint-cells* (e.g. of sympodial hairs), Gliederzellen (p. 1120).

K

Knobs (on cuticle, walls of hairs, &c.), Knötchen; *knob-like*, knopfartig, knötchenartig; *knob-shaped*, knopfförmig; *knobs due to hairs*, Haarknötchen (pp. 1110, 1111).

L

Laciniae (of leaves, &c.), Lacinien, Zipfel; *glandular laciniae*, Drüsenzipfel (cf. p. 337); *laciniate* (divided into narrow lobes), zerschlitzt.
Lacunar (applied to spongy tissue, &c.), lückig, lakunös.

Lageniform, flaschenförmig.
Lamella, having the form of a, lamellenförmig, lappenförmig; *lamellated* (composed of thin plates), blätterig, geschichtet; *lamellated cork*, Lamellenkork (p. 1148); *transverse lamellation*, Querlamellierung (cf. p. 532).
Lash-like, pfriemlich.
Latex-receptacles, Milchsaftbehälter (pp. 1096, 1102, 1103); *latex-sacs* (= laticiferous sacs), Milchsaftschläuche (pp. 1096, 1097).
Laticiferous canals, Milchsaftgänge (cf. p. 412); — *cells* (*non-articulated laticiferous tubes*), ungegliederte Milchsaftröhren (p. 1102); — *hairs*, Milchsafthaare (pp. 1117, 1126); — *sacs*, milchsaftführende Zellen, Milchsaftzellen (pp. 1096, 1097); — *tubes*, Milchröhren, Milchsaftröhren; — *vessels* (*articulated laticiferous tubes*), gegliederte Milchsaftröhren (p. 1103).
Layers of mucilage (subepidermal), Schleimschichten (p. 1088).
Lenticels (*cortical pores*), Lentizellen (Rindenporen) (p. 1149).
Lenticular (i.e. lens-shaped), linsenförmig.
Lepides (small scales, q.v.).
Libriform tissue (i.e. composed of narrow cells with thick woody walls), Libriformgewebe (p. 1135, footnote).
Lid-cells (of glands, e.g. p. 585), Deckelzellen.
Lignified lamella (in wall of guard-cells), Holzlamelle (p. 1082).
Ligulate (i.e. tongue-shaped), zungenförmig.
Lithocyst (i.e. the cell containing a cystolith Lithocyst, Trägerzelle (p. 1112).
Lobed xylem-mass, gelappter Holzkörper (p. 1166); *lobe-like*, lappenartig, lappenförmig.
Loculi (of chambered crystal-fibres, see under *chambered*), Fächer.
Longitudinal fission (of the stem in anomalous growth), Längsspaltung (p. 1166).
Loose (applied to spongy tissue), locker.
Lower scale (of peltate hairs, &c.), unteres Schülferchen (p. 1121).
Lumps (on cell-walls, &c.), Höcker.
Lyrate (applied to shape of two-armed hairs), lyraartig gestaltet.

M

Malformed, distorted (perforations), Krüppelformen (p. 1137); *malformed stomata*, verbildete Spaltöffnungen (p. 1110).
Malpighian hairs (i.e. two-armed hairs, q.v.), Malpighische Haare.
Mammiform (i.e. teat-shaped), *mammilliform*, zitzenförmig.
Many-fluked (applied to anchor-hairs), mehrzinkig.
Marginal-bast, Randbast (p. 1090); *marginal pits*, Randtüpfel (p. 1072).
Marking (of the cuticle), Zeichnung (p. 1071).
Mechanical support (of a stem, &c.), Festigung.
Medullary bundles, &c., markständige Bündel (p. 1157), &c.; *medullary rays*, Markstrahlen (p. 1143); *medullary sheath* (i.e. tracheides forming a circle round the periphery of the pith), Markscheide; *medullary ray-parenchyma*, Markstrahlparenchym; *medullary tissue*, Markgewebe (p. 1133).
Membrane-mucilage, Membranschleim (p. 1098).
Membranous, häutig.
Mesh-like spaces (in the spongy tissue, cf. p. 229), Maschenräume.
Metatracheal parenchyma (p. 1143).
Middle layer (of leaves and glands), Mittelschicht (p. 1087).
Monoclinic crystals, monokline Kristalle (p. 1104).
Monostele (p. 1156).
Morulose glands (cf. p. 748), Maulbeerdrüsen.
Mucilage-canals, Schleimgänge (p. 1099); *-cavities*, Schleimlücken (p. 1099); *-cells*, Schleimzellen (p. 1098); *-glands*, Schleimdrüsen (pp. 1128, 1133); *-hairs*, Schleimhaare (pp. 1127, 1128); *-lacunae* (cf. p. 752), Schleimlakunen; *pores* (cf. p. 336), Schleimspalten.
Mucilaginous epidermal cells, verschleimte Epidermiszellen (p. 1074); *mucilaginous cells*, verschleimte Zellen; *mucilaginous cork*, Schleimkork (p. 1148).
Multiple crystals (cf. p. 95), Verwachsungen von Einzelkristallen.
Multiseriate (i.e. composed of several rows or layers of cells), mehrzellreihig (applied to hairs), mehrschichtig, mehrreihig (applied to medullary rays, epidermis, &c.).
Muriform parenchyma (i.e. made up of brick-shaped cells, cf. p. 682), Mauerparenchym.
Myrosin-cells, Myrosinzellen (p. 1097).

N

Neck-cell (of hairs, cf. pp. 553, 585), Halszelle; *neck-portion* (of glands, cf. p. 287), Halsteil.
Nectarial glands, Nektardrüsen (p. 1131); *nectarial spots*, Nektarflecke (p. 1132).
Nectaries, Nektarien (p. 1130).
Neighbouring cells (of stomata), Nachbarzellen (p. 1078).
Nodose, nodular (applied to thickening), knotig.
Non-articulated, ungegliedert.
Nuclear crystalloids, Zellkernkrystalloide (p. 1109).

O

Obconical, verkehrt (umgekehrt) kegelförmig.
Oblate-spherical, abgeflacht kugelig.
Octahedral crystals (p. 1104).
One-armed hairs, einarmige Haare (pp. 1118, 1119); *one-sided zones of growth* (cf. p. 608), einseitige Zuwachszonen.
Opaque dots (in the leaf), undurchsichtige Punkte (p. 1099).
Open secretory cavities, ungeschlossene Sekretlücken (p. 1100).
Openings (equivalent to *perforations*, q.v.).
Orifice, ostiole (of a nectary, &c.), Mündung, Ostium.
Outer respiratory cavity (of stomata), äussere Atemhöhle (p. 1085).

P

Palisade-glands (cf. p. 306), Pallisadendrüsen.
Panduriform (biscuit-shaped, fiddle-shaped), biskuitförmig, geigenförmig.
Papilliform (applied to hairs), papillenartig.
Papillose differentiation (of the epidermis of the leaf), papillöse Ausbildung (p. 1073).

Paratracheal parenchyma (p. 1143).
Parenchyma-sheath (of veins), Parenchymscheide (p. 1089).
Parenchymatous pericycle (p. 1152).
Partial bands (of spiral thickening), Teilbänder.
Patelliform, becherförmig; *patelliform glands*, Schüsseldrüsen (cf. pp. 602, 604).
Pearl-glands, Perldrüsen (pp. 1126, 1129).
Pedestal (of a hair), Postament, Sockel.
Pegs, Zapfen; *peg-like*, zapfenartig; *peg-shaped*, zapfenförmig.
Pellucid dots, pellucide Punkte (p. 1096); *pellucid*, wasserhell.
Peltate, schildförmig; —*glands*, Schilddrüsen (p. 1128); — *hairs* (*scales*, *lepides*), Schildhaare (pp. 1115, 1118, 1119, 1120); — *scales*, Schülferchen; *false peltate scales*, Scheinschülferchen.
Penicillate (applied to hairs), pinselförmig.
Perforations, Perforationen, Gefässperforationen, Durchbrechungen (p. 1137).
Periaxial wood, periaxiales Holz (p. 1145).
Pericycle, Pericykel (p. 1152).
Perimedullary, i.e. in the outermost zone of the pith.
Petiolar glands, Blattstieldrüsen (p. 1131).
Phelloderm (p. 1149).
Phelloid-cells, Phelloidzellen (p. 1148).
Phloem-islands, Phloeminseln (p. 1161).
Pit, *small pit* (in leaf, &c.), Grübchen; *pit* (in cell-wall), Tüpfel; *pit-canals*, Tüpfelkanäle, Porenkanäle; *pit-like*, grubig, grübchenartig; *pit-perforations* (cf. p. 333), Tüpfelperforationen.
Placentiform (shaped like a flat cake), kuchenförmig.
Plexus (e.g. of fibres), Geflecht.
Plug of lime, Kalkausfüllung (p. 1111); *plug of silica*, Kieselausfüllung (p. 1110); *plugged stomata*, verstopfte Spaltöffnungen (p. 1085).
Polystelic (p. 1156); *apparent polystely* (p. 1157).
Pouch (applied to part of the complicated secretory cells of Magnoliaceae, Canellaceae, &c., cf. p. 1096), Beutel.
Powdery (applied to crystal-sand), mehlartig.
Primary cortex (p. 1150).
Projections (of hairs, &c.), Vorsprünge.
Proliferations, Wucherungen (cf. *excrescence*).
Prominences (on cell-walls, &c.), Vorsprünge, Höcker.
Prong-cells (cf. p. 304), Zackenzellen; *prongs* (of anchor-hairs, &c.), Zacken.
Prop-cells (cf. p. 710), Strebezellen.
Protective sheath (of vascular system), Schutzscheide (cf. pp. 1089, 1151) (see also *endodermis*).
Protrusions (of walls of hairs, &c.), Ausbuchtungen, Ausstülpungen.
Protuberances (of cell-walls, &c.), Protuberanzen, Ausstülpungen.
Pseudocellular, zellenähnlich.
Pulvini, Gelenkpolster, Schwellpolster (p. 1094).
Punctate (of cell-walls, &c.), punktiert; *punctiform*, punktförmig.
Pyriform (pear-shaped), birnförmig.

Q

Quadratic crystals (p. 1104).

Radiate (structure), strahlig.
Raised dots (cf. p. 625), vorspringende Punkte.
Rampart (of cells, &c.), Wall; *rampart of cuticle*, Cuticularwall.
Raphides, Rhaphiden (p. 1104); *raphide-cells*, Raphidenzellen; *-needles*, Rhaphidennadeln; *-sacs*, Rhaphidenschläuche (pp. 1098, 1104); *bundles of raphides*, Rhaphidenbündel (p. 1106).
Raphidines, see *acicular fibres*.
Rayed bundles (in the petiole), 'Faisceaux rayonnés' (of Bouygues, p. 1094).
Rays (of stellate or peltate hairs, &c.), Strahlen; *ray-cells*, Strahlenzellen; *ray-formation*, Strahlenbildung; *ray-portion*, Strahlteil; *many-rayed*, mehrstrahlig, vielstrahlig.
Recurved (of hairs, &c.), umgebogen.
Reniform (kidney-shaped), nierenförmig.
Réseau de soutien, strengthening network (p. 1168).
Reservoir-tracheides, Speichertracheiden (see *storage-tracheides*).
Resiniferous (i. e. containing resin), harzführend.
Resinocysts (cf. p. 402), Resinocysten.
Respiratory cavity (of stomata), Atemhöhle.
Reticulate, netzartig; *reticulate perforations* (cf. p. 561), Netzperforationen (p. 1137); *reticulate xylem-mass* (cf. p. 227), umstrickter Holzkörper; *reticulately heterogeneous pith* (i. e. in which the active cells form a network between the empty ones), netzförmig heterogenes Mark (cf. p. 1134).
Retiform, gitterförmig.
Retort-shaped hairs, Retortenhaare (p. 1129).
Reversed orientation, verkehrte Orientierung.
Revolute (margins of leaves), umgerollt.
Rhombohedra, Rhomboëder, Hendyoëder (pp. 1104, 1105); *rhombohedral*, rhomboëdrisch, hendyoëdrisch.
Ribbed axes, gerippte Achsen (p. 1166).
Ribbon-shaped (applied to hairs), bandförmig.
Ridge, Leiste; *ridge-like* (of thickenings), leistenförmig.
Ring-bark, Ringelborke (p. 1147); *ring-wood* (cf. p. 206), Ringholz (p. 1145).
Rings of growth, Zuwachsringe (p. 1163).
Rods, small, Stäbchen; *rod-cells*, Stabzellen (p. 1155); *rod-cell-sclerenchyma*, Stabzellensklerenchym; *rod-like*, stäbchenartig; *rod-shaped crystals*, stäbchenförmige Kristalle (p. 1106).
Rolled leaves, Rollblätter (pp. 1084, 1087).
Rosette (of epidermal cells around stomata, &c.), Kranz, Rosette; *like a rosette* (*rosette-like*), kranzförmig.

S

Saccate (bag-shaped), schlauchartig.
Sacs, Schläuche; *sac-cells* (cf. p. 57), Schlauchzellen; *sac-like*, *sack-shaped*, schlauchartig, schlauchförmig, sackartig.
Salt-glands, Salzdrüsen (p. 1133).
Sap-wood, Splint, Splintholz (see under *splint-wood*).
Saucer-like (depressions), schalenartig.
Scalariform perforations, leiterförmige Durchbrechungen (p. 1137); — *bordered pits*, Trep-

penhoftüpfel, treppenartige Hoftüpfel (pp. 1139, 1140); — *sieve-plates*, leiterförmige Siebplatten (p. 1154).

Scales, small (*lepides*), Schülferchen (see under *peltate hairs*); *scales of lime*, Kalkschüppchen; *scale-bark*, Schuppenborke (p. 1147); *scale-hairs*, Schuppenhaare; *scaly*, schuppig; *scale-like*, schülferchenartig.

Schizolysigenous (i.e. arising first by separation of cells, but then enlarging by the actual breaking down of cells), schizolysigen.

Sclerenchymatous investment (of vascular bundles), Sklerenchymbeleg (p. 1089); *sclerenchymatous pericycle* (p. 1152).

Scutiform (peltate), schildförmig.

Secondary vascular bundles (p. 1164); *secondary groups of wood and bast*, sekundäre Holzbastgruppen (p. 1163).

Secretory canals (*passages*), Sekretgänge (p. 1101); — *cavities*, Sekretlücken (p. 1099); — *cells*, Sekretzellen (p. 1096); — *lacunae* (cf. p. 740), Sekretlakunen; — *receptacles*, Sekretbehälter (p. 1095); — *sacs*, Sekretschläuche (p. 1096).

Semilunar, halbmondförmig.

Semi-Malpighian (*i.e. one-armed*) *hairs*, halbmalpighische Haare (pp. 1118, 1119).

Sensitive hairs, Fühlhaare; *sensitive pits* (on tendrils), Fühltüpfel.

Septate (of fibres, &c.), gefächert, septiert; *septation*, Fächerung; *septation of the pith without sclerosis*, Fächerung des Markes ohne Sklerose (p. 1134).

Seriated, gereiht.

Serpentine (applied to hairs), schlangenartig, schlangenförmig.

Serrated cuticular crests, gebirgskammähnliche Cuticularleisten.

Shaft (applied to stomata, cf. p. 492), Schacht.

Shaggy hairs (*villi*), Zotten (pp. 1115, 1123); *clothing hairs of the shaggy type*, Deckzotten (p. 1123).

Sheathing (of the veins with crystals), Pflasterung (cf. p. 1108).

Shield (of a peltate hair), Schild.

Short-membered (sclerenchyma, &c.), kurzgliedrig.

Sickle-like hairs (cf. p. 379), Sichelhaare.

Sieve-fields, Siebfelder (p. 1154); *sieve-pit-like structure*, *sieve-plate structure* (of bordered pits), Siebtüpfelstruktur (pp. 1139, 1140).

Silica, Kieselsäure (p. 1109); *silica-bodies*, Kieselkörper (p. 1110); *silica-plugs*, Kieselfüllungen (p. 1110); *silica-sacs*, Kieselschläuche.

Silicification, Verkieselung (p. 1109); *silicified*, verkieselt; *siliceous concretions* (cf. p. 675), Kieselkonkretionen; *siliceous excretions*, Kieselausscheidungen (p. 1110).

Simple clothing hairs, einfache Deckhaare (p. 1115); *simple-pitted* (vessels, &c.), einfach getüpfelt.

Sliding growth (i.e. growth leading to the intercalation of new elements between those already present), gleitendes Wachstum.

Slits, Spalten; *slit-like* (*-shaped*) *pits*, Spalttüpfel; *slit-shaped*, spaltenförmig.

Solitary crystals, Einzelkristalle (pp. 1104, 1105).

Spear-shaped, spiessförmig, spiessig.

Speckled (appearance of leaves), gesprenkelt.

Sphaerites, *sphere-crystals*, Sphaerite (pp. 1104, 1105); *sphaerocrystalline*, sphaerokristallinisch; *sphaerocrystals*, *sphere-crystals*, Sphaerokristalle (p. 1108).

Spicular cells, Spikularzellen (p. 1091).

Spines, Stacheln (p. 1115).

Spiniform, spiessförmig; *spiny hairs* (cf. p. 22), Stachelhaare (p. 1122); *spiny* (of clustered crystals), stachelig.

Splint-wood, Splint (p. 1136).

Split (*cleft*) *xylem-mass*, zerklüfteter Holzkörper (p. 1167); *splitting up* (of xylem-mass, &c., i.e. cleavage), Zerklüftung (p. 1166 et seq.); *splitting* (of the stem, &c.), Spaltung.

Spongy cork, schwammiger Kork, Schwammkork (p. 1148).

Spreading-armed (spongy cells), gespreiztarmig (p. 1087).

Starch-sheath, Stärkescheide (p. 1151).

Stele (p. 1156).

Stellate, sternförmig; *stellate hairs*, Sternhaare (pp. 1115, 1118, 1119, 1121).

Stereides (i.e. a lignified strengthening cell), Stereiden.

Stereom-sheath (i.e. strengthening sheath of veins, leaf-margin, &c.), Stereombeleg.

Stinging bristles (cf. p. 379), Brennborsten; *stinging hairs*, Brennhaare (p. 1118).

Stomatal apparatus (i.e. the guard-cells together with the subsidiary cells, when present), Spaltöffnungsapparat (p. 1078); — *groups*, Spaltöffnungsgruppen (p. 1084); — *pits*, Spaltöffnungsgrübchen (p. 1084); regarding other terms applied to stomata, see p. 399.

Stone-cells, Steinzellen (p. 1090); *stone-celled cork* ('*cork made up of stone-cells*'), Steinzellenkork (p. 1148); *stone-cork*, Steinkork (p. 1148).

Storage-tracheides, Speichertracheiden (p. 1091).

Straight (applied to walls of epidermal cells in surface-view), gerade, geradlinig (p. 1070).

Stratified, geschichtet; *stratiform* (arrangement), schichtenweise (Anordnung).

Strengthening ring, Festigungsring.

Stretching, Zerrung.

Striae, Strichelchen; *striate* (thickening), streifig; *striated*, gestreift; *striation* (of cuticle, &c.), Streifung.

Strigae (= bristle-hairs), Striegelhaare.

Striulations, *striulae* (in leaves, &c.), Strichelchen.

Styloids, Styloiden (pp. 1004, 1106).

Subcentric (leaf-structure), subzentrisch (p. 1086).

Subpapillose (epidermal cells), subpapillös (p. 1073).

Subsidiary cells (of stomata and hairs), Nebenzellen (p. 1078).

Subulate, pfriemenförmig, pfriemenartig gestaltet.

Successive rings of bundles, successive Bündelringe; *successive rings of growth*, successive Zuwachsringe (p. 1163); *successive zones of growth*, successive Zuwachszonen (p. 1163).

Sunk (of stomata, &c.), eingesenkt (see p. 1085).

Supporting network, 'réseau de soutien' (p. 1168).

Supravasal (i.e. situated opposite the xylem-groups in the root).

Swellings, Verquellungen; *swollen*, verquollen.

Sympodially branched hairs (p. 1120).

T

Tabular (applied to shape of cells, &c.), tafelförmig, plattenförmig; *tabular cork*, Plattenkork (p. 1148).
Tannin-cells, Gerbstoffzellen; *-contents*, Tannin-gehalt, Gerbstoffgehalt; *-idioblasts*, Gerbstoffidioblasten (pp. 1095, 1098); *-sacs*, Gerbstoffschläuche.
Tanniniferous (i.e. containing tannin), gerbstoffhaltig.
Teeth, *spines* (of a crystal), Zacken.
Tensile strength, Zugfestigkeit.
Tertiary thickening-layer (in vessels, tracheides, &c.), tertiäre Verdickungsschicht.
Tessellated epithelium, Pflasterepithel.
Tetragonal (crystals), quadratisch; *tetragonal octahedra*, Quadratoktaëder (cf. p. 1104).
Tiers (of candelabra-hairs, &c.), Etagen, Stockwerke; *tier-like*, etagenförmig; *tier-like structure of the wood*, Etagenbau des Holzkörpers (p. 1145); *tier-like cork*, Etagenkork (p. 1148).
Tomentum, Filz.
Torose (thickening), wulstig.
Tortuous (of hairs), hin und hergebogen, geschlängelt.
Tracheides, Tracheiden (p. 1135, footnote); *broadened (enlarged) terminal tracheides*, erweiterte Endtracheiden (p. 1092); *tracheide-sclerenchyma* (cf. p. 446), Tracheidensklerenchym.
Translucent, durchscheinend.
Transparent dots, durchsichtige Punkte (pp. 1074, 1088, 1091, 1096, 1108, 1130); — *lines*, durchsichtige Linien (pp. 1102, 1104); — *striulae*, durchsichtige Strichelchen (p. 1108).
Truncated, abgestumpft.
Tuberculate, höckrig; *tubercles*, Höcker.
Tuberous, knollig.
Tubular (applied to cells, hairs, &c.), röhrenartig, schlauchförmig, schlauchartig.
Tuft, Büschel; *tuft of rays*, Strahlenbüschel; *tufted*, büschelig ausgebildet; *tufted hairs*, Büschelhaare (p. 1121).
Turbinate, kreiselförmig.
Twin-crystals, Zwillingskristalle (p. 1104); *twin-forms*, Zwillingsbildungen; *-stomata*, Zwillingsspaltöffnungen (p. 1085); *-trichomes* (cf. p. 16), Zwillingstrichome; *-glandular hairs*, (cf. p. 484), Drüsenhaarzwillinge.
Two-armed hairs (Malpighian hairs), zweiarmige Haare (pp. 1117, 1119, 1122).
Tyloses, Thyllen (p. 1137).

U

Undulated (applied to walls of epidermal cells in surface-view), wellig gebogen, buchtig wellig (p. 1070); *undulated stems* (cf. p. 289), gewellte Stämme.
Unequal (uneven) increase (of the wood), ungleichmässiger Zuwachs (p. 1166).
Uniform (i.e. homogeneous, applied to the mesophyll), gleichförmig.
Unilateral (one-sided) *bordered pits*, einseitige Hoftüpfel (p. 1140).
Uniseriate (i.e. composed of a single row of cells), einzellreihig, einreihig; *bi-seriate*, &c., zweizellreihig, zweireihig, &c.
Upper scale (of peltate hairs, &c.), oberes Schülferchen (pp. 1121, 1122).
Upright (cells in medullary rays), stehend (p. 1144).
Urceolate, krugförmig.
Urn-shaped (trichomes), urnenförmige Trichome (p. 1119).

V

Ventral (ventricose) part (of glands, cf. p. 319), Bauchteil.
Ventricose (applied to shape of cells), bauchig.
Vermiform (i.e. worm-shaped), wurmförmig, wurmartig.
Verrucose (*wart-like*), warzig.
Vertical direction (in the axis), axile Richtung, Längsrichtung.
Vertically transcurrent (applied to veins), durchgehend; *vertical transcurrence*, Durchgehen (p. 1089).
Vesicles, Bläschen; *vesicular*, blasig, blasenartig; *vesicular hairs*, Blasenhaare (pp. 1076, 1116).
Vessel-perforations, Gefässdurchbrechungen (p. 1137).
Vestibule (of stomata, equivalent to outer respiratory cavity), Kamin (p. 1085).
Vitreous (i.e. transparent as glass), glasartig.

W

Warts, Warzen (p. 1115); *wart-like* (see *verrucose*), warzenartig; *wart-shaped*, warzenförmig.
Water-pores, Wasserspalten (p. 1085); *-receptacles*, Wasserbehälter; *-reservoirs*, Wasserspeicher, Wasserreservoire (p. 1092); *-storing*, wasserspeichernd.
Wavily folded (walls), wellig gefaltet; *wavily nodular striation* (of the cuticle, cf. p. 70), wellig-wulstige Streifung; *wavy* (applied to hairs), kraus.
Weal, Wulst.
Wedges of bast, Bastkeile (p. 1166); *wedged in* (applied to position of hairs, &c., with reference to other cells), eingeklemmt, eingekeilt; *wedge-shaped* (*in the form of wedges*), keilförmig.
Whip-like hairs, Peitschenhaare (cf. p. 401).
Winged axes, geflügelte Achsen (p. 1166).
Wood-fibres, Holzfasern; *wood-parenchyma*, Holzparenchym (p. 1143); *wood-prosenchyma*, Holzprosenchym (pp. 1135, footnote, 1141); *wood-vessels*, Holzgefässe (p. 1136).
Wrinkled (applied to cell-walls), runzelig.

X

Xylem-mass, Holzkörper, — *with tier-like structure*, stockwerkartig aufgebauter Holzkörper (p. 1145).

ERRATA

PAGE 17, line 7 from bottom, first half should *read* '*from being wetted, and to form an air-chamber*'.
24, thirteenth line of third paragraph, for 'Bejuco de aqua' read 'Bejuco de agua'.
57, line 2 of last paragraph, insert a semicolon after 'Léger'.
64, top line, *for* 'place' read 'plane'.
71, line 9 of first paragraph, for 'spread' read 'spreading'.
75, description of Fig. 19, c should read '*C. zeylanica*, L.'.
95, last line, for 'resent' read 'present'.
118, last line of first paragraph, before the word 'recorded' insert 'has been'.
136, first line of second paragraph, for 'developed' read 'deposited'.
141, last line of fourth paragraph (under 5), for 'Dipterocarpous' read 'Dipterocarpeous'.
192, fifth line of last paragraph, for 'see note 2, p. 215' read 'see note 1, p. 190'.
201, fifth line of third paragraph, insert a semicolon after 'hairs'.
204, description of Fig. 48, E–F, for '*Goniocaryum*' read '*Gonocaryum*'.
206, second line of first paragraph, for '*Goniocaryum*' read '*Gonocaryum*'.
206, last line but one of first paragraph, for '*Chlamydcarya*' read '*Chlamydocarya*'.
214, for 'Hippocrateacea' read 'Hippocrateaceae'.
255, ninth line of first paragraph, after '*Platymiscium*' insert a comma.
280, twenty-second line from bottom, for '*Spathylobus*' read '*Spatholobus*'.
334, footnote, for '*Brunai*' read '*Brunia*'.
343, footnote, first word on second line should read 'Gyrocarpeae'.
366, last line but six of second paragraph, for '*Ptermandra*' read '*Pternandra*'.
366, last line, for '*Dyssochaete*' read '*Dissochaeta*'.
374, first line, after '*Trapa*' remove the semicolon.
389, fourth line, for 'laticiferous cells' read 'laticiferous sacs'.
391, fifth line from bottom, read 'cystoliths'.
396, fourth line, for '*verticellata*' read '*verticillata*'.
399, third line from bottom, for '*C. Urticae*, A. DC. *B. hispida*' read '*C. Urticae*, A. DC. *β hispida*'.
408, eleventh line from end of first paragraph, for '*Opunita*' read '*Opuntia*'.
420, third line, for '*offcinale*' read '*officinale*'.
439, fifth line from end of first paragraph of Caprifoliaceae, for 'stuited' read 'tufted'.
500, ninth line, for '*Goniolmon*' read '*Goniolimon*'.
504, twelfth line, for 'rigidity' read 'flexile strength'.
508, footnote 1, for 'Sapotaceae' read 'Ilicineae', and for 'Ilicineae' read 'Sapotaceae'.
534, footnote, for '*Argel*' read '*Arghel*', and for 'described a' read 'described as'.
535, footnote 4, first word in line 2 should read 'intraxylary'.
563, first line of third paragraph, after 'within certain limits' insert 'it'.
566, last line of first paragraph, for 'Ipomoceae' read 'Ipomoeae'.
568, twelfth line from bottom, after 'Fig. 129, *J*' insert a comma in place of the full stop.
573, second line of Cuscuteae should read 'poor in chlorophyll'.
633, last word of fourth line should read 'thin'.
647, fourth line of first paragraph, for 'De Barry' read 'De Bary'.
694, second line of first paragraph, for 'Fig. 159, C' read 'Fig. 169, C'.
712, tenth line from bottom, for 'vestibule' read 'front cavity'.
721, in the second line read '*Gonystylus*, *Aszlerum* and *Amyxa*'.
764, fourth line of Urticaceae, for 'Arctocarpeae' read 'Artocarpeae'.
766, second line of second paragraph, for '*C. Kraussiana*' read '*Celtis Kraussiana*'.
779, last line but one of Thelygoneae, for 'or ans' read 'organs'.
823, first line of third paragraph, for 'Hewitt' read 'Leavitt'.
835, last line but one of second paragraph, for 'simpler' read 'simple'.
841, fourth line, for '*Tsoptera*' read '*Isoptera*'.
845, footnote, for 'latiferous' read 'laticiferous'.

Note. It was stated in the Editorial Preface to Vol. I that the English edition had received from the author's hand all the emendations embodied in the new German edition. Since this preface was written it has been ascertained that some small additions were made to the German edition while in the press, and too late to be incorporated in the translation.